SEDIMENTOLOGY AND DEPOSITIONAL ENVIRONMENTS OF THE MIDDLE DEVONIAN BIG BEND ARKOSE AND BURDEKIN FORMATION, FANNING RIVER GROUP, BURDEKIN SUBPROVINCE, NORTH QUEENSLAND, AUSTRALIA.

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Twelve distinct facies have been recognised for the Middle Devonian, (?Eifelian-Givetian), Big Bend Arkose and Burdekin Formation of the Fanning River Group, Burdekin Subprovince, north Queensland. They represent deposition within the restricted Burdekin Basin in non-marine, shallow-water inner and proximal marine shelf, and shallow to moderate depth distal shelf environments. Non-marine deposition (unfossiliferous coarse siliciclastic facies) took place within restricted coastal plains, and represents coarse-grained channel and finer-grained floodplain deposits developed above *in situ* weathering profiles. Deposition within the inner shelf was complex, highlighting local influences of coarse siliciclastic input, inner shelf carbonate production and an across-shelf siliciclastic to carbonate transition. Facies deposited in the inner shelf were: (1) abraded coarse siliciclastic facies representing inundated marine headlands, and upper shoreface coarse siliciclastic deposition; (2) fossiliferous sandstone facies deposited in the subtidal lower shoreface; (3) fossiliferous siltstone facies, representing restricted fine-grained siliciclastic-dominated, nearshore, subtidal embayments; (4) nodular limestone facies deposited within mostly subtidal carbonate-dominated impure lagoons with local patch-reef development; and (5) impure limestone-sandstone facies representing sporadic deposition of mobile coarse siliciclastic sand bodies within an impure, subtidal carbonate lagoon. Deposition on the proximal shelf was dominated by stromatoporoid biostromal facies (seven divisions) representing biohermal (reefal) deposition (framestone), back reef and intrabiostromal stromatoporoid pavement (coverstone), interreef channel (grainy floatstone), extensive biostromes and storm-reworked equivalents which developed from the nearshore zone across the shallow shelf (silty rubbly floatstone, micritic stromatoporoid floatstone, rudstone, associated packstone and wackestone). Reef and biostromal growth took place with moderate levels of siliciclastic input, in proximity of granitic hinterlands and can be considered as preserved "fringing" reef and biostrome. Additionally, where extensive reef or biostrome did not develop, the proximal shelf was inhabited by dispersed stromatoporoid pavement (dispersed stromatoporoid packstone facies). Three facies represent distal shelf deposition, seaward of biohermal or biostromal growth: (1) coralline packstone, representing shallow water, offshore, coral and dendroid stromatoporoid thickets; (2) localised crinoid grainstone deposited as mobile carbonate sand bodies on the shallow distal shelf removed from significant siliciclastic input; and (3) micritic carbonate facies, restricted to the Golden Valley area, representing relatively deeper water deposition at the limits of the photic zone. *Endophyllum* siltstone facies represents growth of small coral-dominant patch reefs in a fine mixed carbonate-siliciclastic environment during initial stages of regression in the uppermost Burdekin Formation within the Fanning River area. Depostion of the lower Fanning River Group was controlled by basement topography and by the restricted nature of basin geography with significant variations across the subprovince. Two styles of shelfal assemblage developed, reflecting the development of a biohermal-dominated proximal shelf in the Fletcherview-Burdekin Downs area whereas in the Fanning River, Golden Valley, and Kirkland Downs areas a low relief biostromal-dominated proximal shelf assemblage developed. □ *Fanning River Group, Burdekin Formation, Big Bend Arkose, Devonian, Givetian, fringing reefs, sedimentology, stromatoporoids, biostromes.*

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The Fanning River Group is the lowermost stratigraphic unit of the Burdekin Subprovince, a Middle Devonian to Carboniferous succession WSW of Townsville, north Queensland (Fig. 1). The Fanning River Group was introduced by Wyatt et al. (1970) as consisting of three forma-

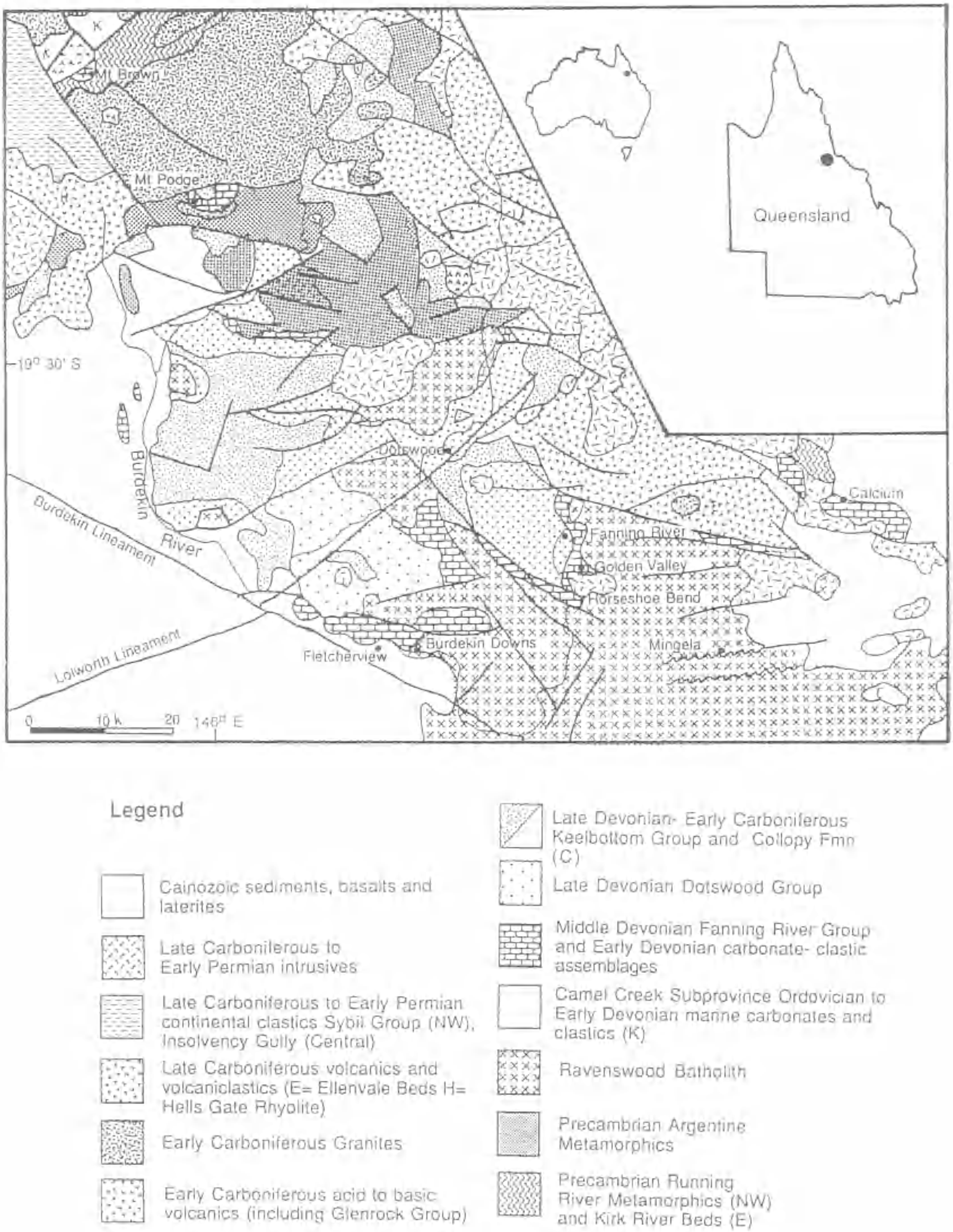


FIG. 1. Geological map of the Burdekin subprovince, after Lang et al. (1990).

tions: Big Bend Arkose (dominantly coarse-grained siliciclastics), Burdekin Formation (a dominantly carbonate succession with some siliciclastic input) and Cultivation Gully Formation (a finer grained silciciclastic formation).

This paper is concerned with the sedimentology of constituent facies of the lowermost two formations of the Fanning River Group. The aim of the following sedimentological analysis is to provide an ecostratigraphic context for study of the abundant stromatoporoid fauna and other faunal elements (Cook, 1993a,b). This study also includes the Laroona Formation and Mt. Podge Limestone. These formations are older than the Fanning River Group, but represent a comparable sedimentary development and they are included for completeness. Stratigraphic sections were measured at sites identified for their stromatoporoid occurrence or sedimentological importance, and key sections were logged in detail with the collection of representative lithological and palaeontological samples. In addition several spot localities were examined where exposure was not conducive to stratigraphic logging.

The Big Bend Arkose and Burdekin Formation are herein divided into twelve facies grouped as non-marine, inner shelf, proximal shelf and distal shelf facies associations. A summary of the stratigraphic distribution of facies is presented in Fig. 2. The facies are briefly characterised, and their relationships determined, facilitating interpretation of the overall facies mosaic and depositional system. Detailed discussion of each facies follows, with inferred characteristics of the physical environment tabulated where possible. Detailed logs are available upon request from the author. Locality numbers used in this work refer to James Cook University of North Queensland register of fossil localities (see Appendix).

STRATIGRAPHY AND AGE

The name Big Bend Arkose was originally employed by Heidecker (1960), but formalised by Wyatt et al. (1970) who established the entire group. Burdekin Formation was an emendation of Burdekin Limestones (Leichhardt, 1847), Burdekin Downs Limestone (Jack, 1879a), Fanning River Limestone and Double Barrel Limestone (Jack, 1879b), Burdekin Beds (Jack, 1886) and Burdekin Formation (Jack and Etheridge, 1892). Wyatt et al. (1970) restricted the formation to the interval of calcareous shale, calcilutite, fossiliferous limestone, coquinite and minor sandstone and shale interbeds above the Big Bend Arkose. They proposed the Cultivation Gully Formation for lithic sandstone and shale with calcareous, coralline interbeds in its lower part that conformably succeeds the Burdekin Formation. The type section for the Fanning River Group is located along the the Fanning River (L788) 3km upstream from Fanning River Station (L788) by Wyatt et al. (1970). Although the Big Bend Arkose and Burdekin Formation are thin and somewhat atypical at this site, it is by far the most complete, well-exposed section. Limited data is available on the precise zonal ages of the lower Fanning River Group. Problems arise from the paucity of conodont faunas in critical parts of the group and the biostratigraphic reliability of rugose corals and *Stringocephalus*.

Stringocephalus, traditionally regarded as *the* Givetian index fossil (cf. Zeigler, 1979) is common in the Fanning River area. Its lowest occurrence is 31m above the base of the group, and is abundantly present in a number of ecologically distinct horizons throughout this section. In addition, *Stringocephalus* is found near the top of the Burdekin Formation at Horseshoe Bend. These data strongly suggest a Givetian age for the bulk of the Burdekin Formation.

Rugose coral associations of Zhen (1991) from the Fanning River Group (excluding Mt. Podge), were given late Eifelian to middle to late Givetian ages. Zhen's (1991) "E" assemblage was given as *ensensis* or slightly younger and is thus Givetian *sensu* Zeigler and Klapper (1985). Assemblage "G", was assigned a late Eifelian to early Givetian, this partially related to the presence of *Stringocephalus*, 60m above the lower limits of assemblage "G". As previously stated, *Stringocephalus* has been subsequently recorded lower in the sequence, in the middle of assemblage "G" of Zhen (1991). A Givetian age for Assmblage "G" is therefor favoured.

Conodont data for the Burdekin Formation are limited. Conodonts indicative of *varcus* zone age were reported by Zhen (1991) from Turtle Creek in the NE of the Subprovince. Limited conodont data has become available on the age of the Burdekin Formation and the Mount Podge sequence from the work of Talent & Mawson (1994). Material processed from the Fanning River type section, Kirkland Downs and Burdekin Downs yielded conodonts which indicate a predominantly Givetian age for the sequence. Conodonts within the upper two thirds of the type section are of middle to late *varcus* age (Talent & Mawson, 1994). This conclusion combined with

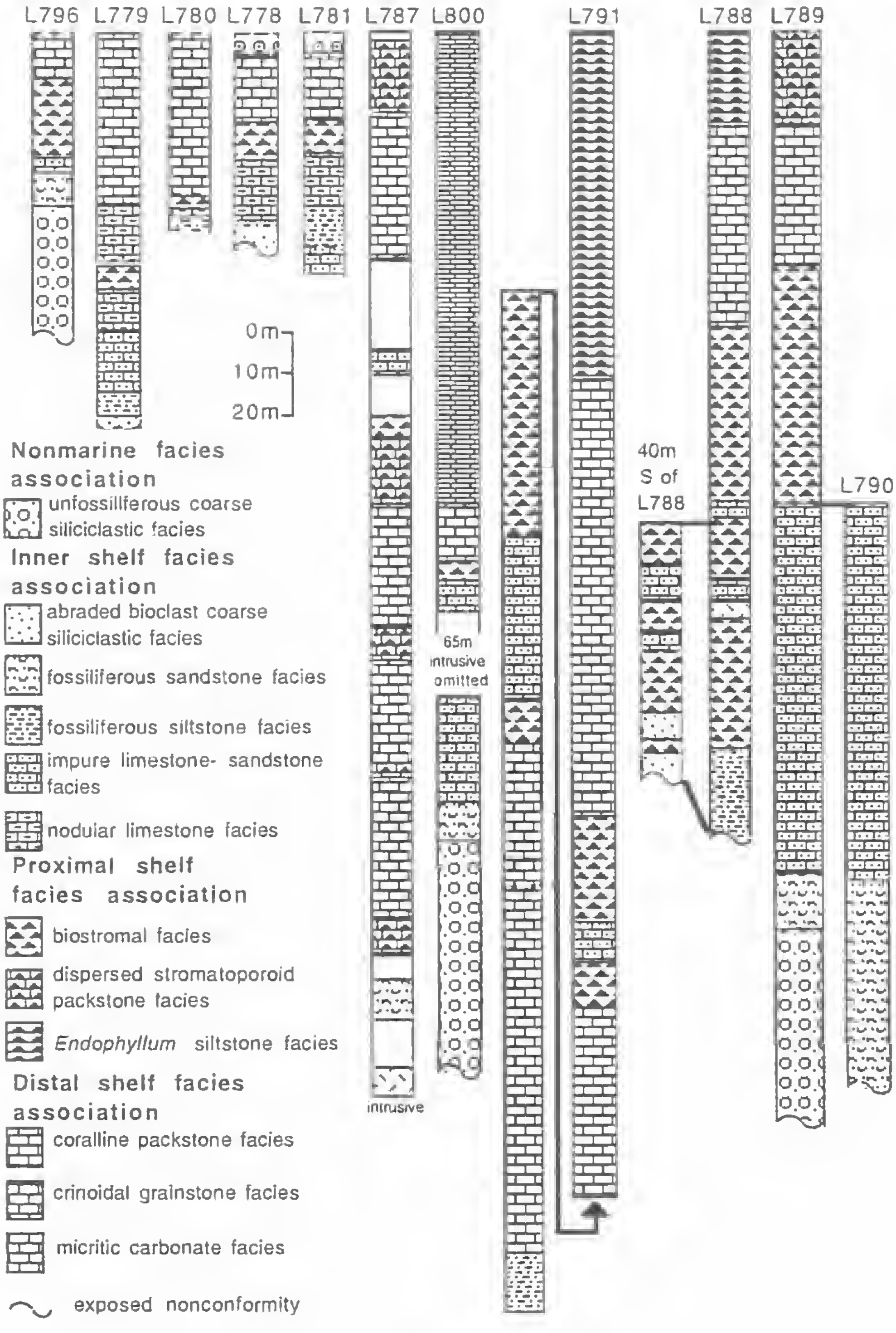


FIG. 2. Facies associations in principle sections for the lower Fanning River Group. For localities refer to Appendix.

the occurrence of *Stringocephalus* extends Givetian ages down to 31m above the unconformity within the Fanning River type section (Talent & Mawson, 1994). This suggests that all of the type section is likely to be of Givetian age. At Kirkland Downs the majority of the sequence lies within the *ensensis* zone, probably late *ensensis*, with upper section within the early *varcus* zone. Limited data from Burdekin Downs suggest a pre-late *varcus* age for at least the lower half of the sequence. Conodonts from Mount Podge show an Emsian-Eifelian age ?late *inversus-serotinus* to *costatus* zones, for most of the succession. A Givetian age, at least early *varcus* zone is indicated for uppermost units in one western Mount Podge section (Talent & Mawson, 1994).

In summary, the age of the Big Bend Arkose and the lower parts of the Burdekin Formation may range into the Eifelian, but most of the Burdekin Formation is of Givetian age with its uppermost sequences ranging into the late *varcus* zone, or perhaps younger.

TERMINOLOGY

Nomenclature of coarse siliciclastics is from Folk (1974) whereas carbonate dominated lithologies are named using the textural classification of Dunham (1962) with modifications from Embry and Klovan (1971) and Tsien (1981). For carbonate-siliciclastic mixtures it is desirable to identify amounts of impurity. Prefixes are applied to carbonate lithologies indicating the percentage range of siliciclastic impurities as follows:

0-5% -carbonate name only
5-10% -slightly impure
0-30% -moderately impure
30-50% -highly impure.

The grain size of the siliciclastic fraction is also indicated. Examples of this approach are "slightly impure fine sandy wackestone" and "highly impure silty floatstone". These terms are also applied to the matrices of boundstone lithofacies to provide a gross guide to the clastic signature of stromatoporoid-bearing lithologies. Siliciclastic-dominated lithologies within the sequence commonly have a significant fossil content. The following prefixes are used as an indication of this:

2-10% -slightly fossiliferous
10-30% -moderately fossiliferous
30-50% -highly fossiliferous.

The word "biostrome" has both a sedimentological and palaeoecological meaning. Its sedimentological use denotes a bedded deposit constructed largely by living organisms and its palaeoecological sense it implies a flat bottomed, low relief community of benthic organisms.

FACIES RELATIONSHIP TO LITHOSTRATIGRAPHY

The contact between the Big Bend Arkose and Burdekin Formation is transitional, and a precise facies boundary between the two cannot be defined. In general however the facies associations can be divided into:

Big Bend Arkose
Unfossiliferous coarse siliciclastic facies
Abraded bioclast coarse siliciclastic facies
Fossiliferous sandstone facies
Burdekin Formation
Fossiliferous siltstone facies
Impure limestone-sandstone facies
Nodular limestone facies
Biostromal limestone facies (seven divisions)
Endophyllum siltstone facies
Dispersed stromatoporoid packstone facies
Coralline packstone facies
Crinoidal grainstone facies
Micritic carbonate facies

FACIES ASSOCIATIONS OF THE BIG BEND ARKOSE AND BURDEKIN FORMATION

NON-MARINE ASSOCIATION

Unfossiliferous coarse clastic facies
(Table 1)

DIAGNOSIS

Localised granitic boulder conglomerate resting on weathered and jointed granitoid basement, or metamorphic cobble conglomerate resting on metamorphic basement. Thick-bedded, unfossiliferous, trough and planar cross-laminated coarse sandstone sporadically interbedded with red or purple sandy siltstone.

DISTRIBUTION AND THICKNESS

FANNING RIVER NORTH: L789; 20m of section consisting of basal conglomerate, interbedded red siltstone and coarse arkosic sandstone. FANNING RIVER CAVES AREA: immediately N of base of section. L791; scattered outcrops of red siltstone and coarse arkose. GOLDEN VALLEY NORTH: L800; approximately 45m thick, <1m basal conglomerate, 5-10m pebbly granule-rich arkosic sandstone and approx 35m of coarse subarkose. ARTHURS CREEK TRIBUTARY: L783; approximately 13m of thin basal conglomerate, over-

TABLE 1. Characteristics of the non-marine facies association. C= common, A= abundant.

NON MARINE FACIES ASSOCIATION				
Facies	Unfossiliferous coarse siliciclastic facies			
Lithology	conglomerate		sandstone	siltstone
	granitic clast	metamorphic clast		
Bedding massive (M), very thick (v), thick (T), medium (m), Thin (h)	M, V-T	M, V-T	M, V- m	M, T - h
planar cross bearing trough X bedding planar lamination ripple X lamination		Crude Minor Crude Imbrication	A C A C	C
Nodules				carbonate
Grain sizes	cobble-boulder	msand-large cobble	fsand-granule, sporadic pebbles	
	sandy or silty mix	sandy or silty mix		
	granite clasts	metamorphic clasts, qtz	Arkose: qtz, felds, bio, hbl, rare aplite rfs, granite rfs	clays, qtz, bio, felds
	qtz, felds, bio, qrfs in mtx	qtz, felds, bio, muscovite, rfs in mtx	Litharenite: muscovite, biotite, qtz, metamorphic rfs	
Fabric	clast supported, unsorted		poorly-moderately sorted	
Lithology	oligmict conglomerate		arkose-subarkose metalitharenite	siltstone-sandy siltstone
Other features	both lie upon jointed basement			Plant fossils reported by Wyatt (1973) from Turtle Creek

lain by red sandy siltstone succeeded by coarse subarkosic sandstone. KIRKLAND DOWNS: L798; approximately 35m of interbedded litharenite, sublitharenite and subordinate green and purple micaceous siltstone. MOUNT PODGE: L801; approximately 5m of trough cross bedded, metamorphic-derived conglomerate overlain by approximately 5m granule-pebble conglomerate.

DESCRIPTION

This facies rests nonconformably on basement and consists of boulder to cobble conglomerate, red-coloured shale and sandy siltstone, and coarse arkose or metalitharenite. Granitic boulder conglomerate lies atop progressions from jointed basement, through weathered corestone fabric to boulder conglomerate supporting a silty or sandy arkosic matrix. The conglomerate intervals are thin, rarely more than 5m thick, and are poorly exposed and locally restricted. Metamorphic conglomerate is thinner, and unconformably overlies analogous, but much thinner, progressions from basement. It often show trough cross bedding and imbrication. Sandstone, which dominates the facies is thickly bedded, commonly planar and trough cross bedded, unfossiliferous coarse arkose or micaceous litharenite. Poorly outcropping, laminated sandy siltstone is uncommon as interbeds and very rarely contain small carbonate nodules.

DISCUSSION

Terrestrial unconformities upon crystalline basement are commonplace in the modern environment, but ancient examples have been rarely reported in the literature (Wahlstrom, 1948; Williams, 1968; Went, 1991). Went (1991) described similar features for early Palaeozoic unconformities, noting corestone fabrics developed upon coarse igneous basement which he interpreted as representing weathering profiles. The progression up-section into the basal Big Bend Arkose indicates a penecontemporaneous (Devonian) weathering profile upon the Ravenswood Granodiorite complex and Argentine Metamorphics.

Conglomerates and other coarse clastics are interpreted as fluvial on the basis of the absence of marine fossils, so abundant in immediately adjacent facies, proximity to basement and localised distribution, and the presence of planar and trough cross beds (Walker, 1984). Siltstones are interpreted as related "floodplain " deposits. Rare carbonate nodules may be reworked caliche nodules, indicative of pedogenesis in arid, hot conditions (Allen, 1974).

The facies represents the *in situ* development of a weathering profile on granitic or metamorphic basement, and coarse pebbly sandstones or pebble conglomerates of fluvial origin deposited on restricted coastal plains in response to rising sea-level.

INNER SHELF AND SHOREFACE ASSOCIATION

Abraded bioclast, coarse silciclastic facies (Table 2)

DIAGNOSIS

Localised granitic boulder conglomerate with interstitial sandstone containing abraded or rarely *in situ* fossils overlying jointed and weathered basement. Coarse sandstone, planar or cross-laminated contain abundant abraded bioclasts.

DISTRIBUTION AND THICKNESS

FANNING RIVER: L788; approximately 5m of basal granitic conglomerate and <1m of coarse subarkose; adjacent section contains two 5m units of medium bedded coarse moderately fossiliferous subarkose separated by a 2.5m biostromal rubble unit. HORSESHOE BEND: L786; 4m of granitic conglomerate succeeded by 2.5m of fining-upwards, medium bedded, moderately fossiliferous subarkose. FLETCHERVIEW: L788; 3m basal granitic conglomerate with silty matrix overlain by a thin unit < 0.8m of thickly bedded coarse-grained, moderately fossiliferous subarkose. L779; 1.7m of thickly bedded moderately fossiliferous pebble conglomerate and very coarse-grained subarkose. BURDEKIN DOWNS: L783; 2m of granitic boulder conglomerate with interstitial encrusting and unabraded fossils within coarse arkosic matrix. Overlying outcrop obscured. HERVEYS RANGE: <5m of moderately fossiliferous metamorphic cobble conglomerate. MOUNT PODGE: approximately 10m coarse-grained, slightly fossiliferous coarse to medium grained sublitharenite. Some units referred to the fossiliferous sandstone facies at Fanning River North and Golden Valley are transitional to the abraded bioclast, coarse siliclastic facies.

DESCRIPTION

The facies is characterised by coarse clastic units containing an abundance of abraded bioclasts. Thin, locally restricted, granitic boulder conglomerate contains common to abundant, abraded fossil bioclasts and rare limestone intraclasts within a dominantly coarse arkosic, or less commonly siltstone matrix (Fig. 3A). These units nonconformably overlie a basement progression akin to that described for the unfossiliferous coarse clastic facies. At L793, granitic boulders display an encrusting fauna of *Stachyodes* and *Alveolites*, and at L786 non-abraded coralline and dendroid stromatoporoids are found in boulder interstices. The facies is dominated by thick bedded slightly to moderately fossiliferous coarse-grained arkose, commonly with sets of low-angle cross and planar laminae. Abraded bioclasts include gastropods, bivalves, abundant tabulate and rugose coral debris and dendroid stromatoporoid debris.

DISCUSSION

Granitic conglomerates represent *in situ* progressions from jointed basement through spheroidally weathered granitoid to boulder conglomerates showing no sign of transport. They are interpreted as rocky headlands or palaeorupicost (Johnson, 1988a) preserved due to rapid transgression accompanying rapid deposition. Lateral relationships indicate a pre-weathered surface which does not fit Johnson's (1988b) genetic classification of rocky shorelines. Preponderance of broken and abraded bioclasts within the matrix suggests intertidal reworking, but encrusting *Stachyodes costulata*, foliose *Alveolites* sp., and non-abraded specimens of the same taxa indicate the continuance of headland bedrock into the subtidal zone. Close vertical and lateral associations with sandstone units suggests continuity with high energy sand deposition adjacent to such headlands. Coarse arkose is interpreted as a shoreface deposit on the basis of abundant broken bioclasts, presence of low angle cross lamination, planar laminae and proximity to basement. These features are consistent with upper shoreface deposition, transitional to lower shoreface, well above fairweather wave base (Reineck and Singh, 1980; Walker, 1984; Reinson, 1984). The facies represents localised rocky marine headlands (rupicost) and associated shoreface deposition.

Fossiliferous sandstone facies (Table 2)

DIAGNOSIS

Thick-bedded, coarse-grained, fossiliferous sandstone containing an abundant molluscan fauna in addition to slightly abraded coralline bioclasts. Uncommon, thin siltstone interbeds are bioturbated and contain an abundant unabraded coralline fauna.

TABLE 2. Characteristics of coarse siliciclastic facies of the inner shelf facies association. Letter in bold= *in situ*, italicised= fragmental and transported, plain text= reoriented or unabraded. R = rare, U= uncommon, C= common, A= abundant.

INNER SHELF FACIES ASSOCIATION					
Facies	Abraded bioclast, coarse clastic facies		Fossiliferous sandstone facies		
Lithology	conglomerate	sandstone	sandstone	siltstone	mudstone/ wackestone
Fauna					
Stromatoporoids					
laminar	*U*	*R*	*R*	*U*	*U*
low-medium domical	*U*	*R*	*R*	*U*	*U*
high domical-bulbous	*U*	*R*	*R*	*U*	*U*
dendroid	R U *U*	*R*	*R*	R *U*	R *U*
Tabulate corals					
ramose alveolitids	R *U*	*R*		R *U*	R *U*
auloporids				U	U
Heliolites	*U*	*R*	*R*	*R*	R
domical alveolitids	R *U*	*R*	*R*	*R*	R
foliose alveolitids	R *U*	*R*	*R*	*R*	R
Rugose corals					
solitary (small)	*U*	*R*	*U*	C	C
colonial					
solitary (long/delicate)		*R*	*R*	R	*R*
Chaetetids	*R*	R	*R*	R	*R*
Bivalves	*C*	*C*	A *A*	A *A*	A *A*
Nautiloids					*R*
Gastropods	*C*	*C*	A *A*	A *A*	A *A*
Crinoids			*R*	R	*R*
Brachiopods	*R*		*R*	*R*	*R*
Bedding features					
massive (M), very thick (v), thick(T), medium (m), thin (h)	**M**	**M, V - m**	**M, V - m**	**T - m**	**T - m**
planar cross bedding		C	C		
planar lamination		C	C	C FINE	U
planar X lamination		C	C		
ripple X lamination				U	R
Nodules		Some Fe	Some Fe	C	C
Styolites; low sinuosity				C	C
Grain sizes					
clastics	boulder to cobble with vcsand or silty mix	fsland-pebble	to vcsand	to vcsand	to vcsand
carbonates	to cobble	to cobble	to cobble	to cobble	to cobble
Bioturbation			many burrows and traces	extensive	extensive
Clastic grain types	dependant upon basement: granitic basement: granitoid, feldspar, qtz, biotite, tourmaline, hornblende. metamorphic basement: meta r.f.s. qtz, muscovite, biotite			qtz, felds, biotite dominant	
Impurity					up to 50%
Other features	rare intraclasts				

DISTRIBUTION AND THICKNESS

FANNING RIVER NORTH: L789; 10m of medium to thickly bedded subarkose interbedded with sandy siltstone, minor carbonate mudstone interbeds near the top, all moderately fossiliferous. L790; 46m of coarse-grained subarkose interbedded with sandy calcareous siltstone towards the top, all moderately fossiliferous. FANNING RIVER CAVES: L791; approximately 15m of thickly bedded, slightly to moderately fossiliferous coarse-grained subarkose. GOLDEN VALLEY NORTH: L800; approximately 8m of thickly bedded coarse subarkose with minor interbedded impure sandy packstone near top. KIRKLAND DOWNS: L796; approximately 8m of thickly bedded fossiliferous coarse sublitharenite. PAYNES LAGOON: approximately 80cm of moderately fossiliferous sublitharenite.

DESCRIPTION

This facies is dominated by thick-bedded, commonly cross bedded, coarse-grained, fossiliferous arkose which is generally displays fine to medium laminae and cross laminae and contains an abundant gastropod and bivalve fauna, in addition to abraded coralline debris. Less common, thin, moderately fossiliferous sandy siltstone interbeds show bioturbation and contain common coralline bioclasts showing limited abrasion. Interbeds of moderately impure silty to sandy mudstone and wackestone are common in the upper part of the association. They contain a scattered coral, dendroid stromatoporoid and molluscan fauna.

DISCUSSION

Unless storm-generated, large coarse-grained sand bodies are restricted to above fairweather wave base which generally falls within 5-15m below sea level (Walker, 1984). Abundance of low angle cross lamination, and *in situ* molluscan and coralline fauna suggest deposition of active mobile sand bodies on the lower shoreface, above fairweather wave base, but below the mean low water mark. A location on the innermost shelf, in very shallow water is indicated. Given the probable small fetch of the Burdekin Subprovince, discussed later, fairweather wave base may have been unusually shallow and a 5m depth is probably a maximum figure. These sand bodies are interpreted to be channel mouth bars and associated merged sheet sands from creeks analogous to small, simple birdsfoot deltas (Walker, 1984; Miall, 1984). A limited distribution reflects basement topography and the position of stream outfalls. Given basement topography, these units may represent mid to distal parts of small fluvial channels bordering the basin which encroach into the shallow marine environment, such as those described by Roberts & Murray (1988) from the northern Red Sea. Transition to the overlying muddier, carbonate-dominant facies represents facies mixing (Mount, 1984) and records a gradation to sheltered subtidal lagoonal environments generally below fairweather wave base.

Fossiliferous siltstone facies
(Table 3)

DIAGNOSIS

Thin-to medium-bedded, bioturbated, sandy siltstone, with sandstone lenticles and stringers, contains an abundant ramose coralline and a shelly fauna. A stromatoporoid biostrome is present at one studied locality. Highly impure wackestone and packstone are common in the upper stratigraphic intervals of the facies.

DISTRIBUTION AND THICKNESS

FANNING RIVER: L788; approximately 15m of sequence, laterally discontinuous, consisting of fossiliferous medium to thin bedded, laminated, nodular siltstone with abundant corals, common sandy stringers and a singular diffuse stromatoporoid biostrome. FLETCHERVIEW: L779; approximately 6m of interbedded siltstone, nodular calcareous siltstone and wackestone with common sandy stringers, abundant coral, *Stachyodes* and molluscan fossils. Minor fenestral limestone. L780; 3m of increasingly calcareous and fossiliferous micaceous siltstone with abundant coral and mollusc fauna. L778; <1m of siltstone beds, abundant coralline fauna, transitional to overlying nodular limestone. BURDEKIN DOWNS: L781; 10m of siltstone interspersed with silty coralline packstone and wackestone, rare sandy stringers all with abundant coral and *Stachyodes* fauna, transitional to overlying nodular limestone association.

DESCRIPTION

This facies consists of thin to medium bedded, laminated, nodular, extensively bioturbated calcareous or sporadically carbonaceous, fossiliferous sandy siltstone containing an abraded and non-abraded branching tabulate coral, solitary rugose coral and molluscan assemblage. Silty sandstone occurs as lenticular stringers or thin to medium bedded, bioturbated, fossiliferous units. Carbonate mudstone and wackestone are moderately impure, becoming more dominant up sequence. These are likewise bioturbated and contain a ramose tabulate and rugose coral fauna. At Fletcherview (L779) algal, laminated, impure limestone is found in one horizon, displaying a weak fenestral fabric. Localised packstone patches are common in impure limestone units. At Fanning River, an unbound stromatoporoid

TABLE 3. Characteristics of inner shelf facies associations; fossiliferous siltstone and impure limestone facies. Letter in bold= *in situ*, italicised= fragmental and transported, plain text= reoriented or unabraded. R= rare, U= uncommon, C= common, A= abundant, D=dominant. # includes rare *Stringocephalus*.

INNER SHELF FACIES ASSOCIATION						
Facies	Fossiliferous siltstone facies			Impure limestone-sandstone facies		
Lithology	siltstone	wackstone-mudstone	biostrome	sandstone	wackestone mudstone	coquinite
Fauna						
Stromatoporoids						
laminar	U *U*		**A**	*C*		
low-medium domical	U *U*		**A**	*C*		*C*
high domical-bulbous	U *U*		**A**			
dendroid	U	*C*	**U**	*U*	C*C*	*U*
Tabulate corals						
ramose alveolitids	D *D*	C *C*		*C*	C *C*	*C*
auloporids	*C*	C *C*	**C**		C *C*	
Heliolites	C *C*	C *C*	**U**	*C*	C *C*	*U*
domical alveolitids	C *C*	C *C*	**C**	*C*	C *C*	*U*
foliose alveolitids	C *C*	R *R*	**U**	*C*	R *R*	
Rugose corals						
solitary (small)	A *A*	A *A*	C	C	A *A*	
solitary (long/delicate)	U *U*	U *U*		*U*	U *U*	
Chaetetids	C	*R*			R	
Bivalves	C *C*	C *C*		C	C *C*	D *D*
Nautiloids	R	*R*			R	
Gastropods	C *C*	C *C*		C *C*	C *C*	C *C*
Crinoids	U	*U*			*U*	
Brachiopods	C *C* l.	C *C*			C *C*	*U*
Bedding features						
massive (M), very thick (v), thick(T), medium (m), thin (h)	**H - m**	**m - T**		**V - T** (sometimes graded)	**m - T**	**m - T**
planar cross bedding				**C**		**C**
planar lamination	**C** FINE	**U** FINE		**C**	**U** FINE	**C**
planar X lamination		**U**		**C**	**U**	**C**
ripple X lamination	**U**	**U**			**C**	
Nodules	**A**	**A**		**A** (Fe nodules)	**A**	**A** (Fe nodules)
Low sinuosity stylolites	**A**	**A**	**U**		**A**	
Grain sizes						
clastics	silt-vcsand	silt-vcsand		csand-granule	silt-vcsand	med sand-small pebble
carbonates	mud cobble	mud cobble		msand- cobble	mud-cobble	msand-cobble
Bioturbation	extensive	extensive		many burrows and traces	extensive	extensive
Clastic grain types	qtz, feldspar, biotite, granitic rfs			qtz, feldspar, hornblende, granitic rfs, metamorphic rfs, biotite, muscovite, tourmaline		
Impurity	clastic rock	up to 50%		clastic rock	up to 50%	up to 50%
Carbonate fabric	n.a.	above	restricted bindstones	n.a.	above	grainstone

biostromal unit occurs as a lenticular body within the fossiliferous siltstone facies.

DISCUSSION

Ubiquitous bioturbation, the dominance of branching corals and stromatoporoids, and the fine grained signature suggests a quiet water, fine siliciclastic, inner shelf depositional environment (Enos, 1983; Belperio & Searle, 1988; Flood & Orme, 1988) either below fairweather wave base or protected from wave energy by offshore biostromal or biohermal barriers. Whereas some sedimentary structures are preserved most have been obliterated by bioturbation and this is typical, but not diagnostic, of inner shelf subtidal deposition (Enos, 1983). Lateral discontinuity at Fanning River implies embayment deposition, whereas more extensive development near Burdekin Downs suggests a broader subtidal siliciclastic zone. Sand stringers represent minor storm admixtures to this subtidal domain (Walker, 1984). The abundance of barely abraded ramose tabulate and solitary rugose corals highlights a dispersed subtidal coralline community. The toppling and some breakage of the ramose coralline fauna suggests some periods of relatively elevated energy conditions such as those induced by storms, but deposition was mostly sheltered from high energy events.

The stromatoporoid biostrome at Fanning River within this facies must have been subtidal in its development. Growth forms of the fauna within this biostrome show a response to fine clastic input (stress?) with multiple overgrowths of stromatoporoids and tabulate corals. By analogy to modern subtidal bay muds and muddy sands on the north Queensland shelf, which extend to the mean low spring tide mark (Belperio & Searle, 1988) water depths for this association can be estimated as probably less than 5m below mean low water mark.

Fenestral limestone found only at the base of the association at L779 is similar to that described by Laporte (1967) and Read (1973) and indicates supratidal exposure as a minor perturbation of local sea level or tectonic adjustments.

Impure limestone-sandstone facies
(Table 3)

DIAGNOSIS

Thick-bedded, commonly cross-laminated coarse sandstone is interbedded with variably impure carbonate mudstone and wackestone. Minor coquinite (coarse, sandy bivalve grainstone) is likewise cross-laminated.

DISTRIBUTION AND THICKNESS

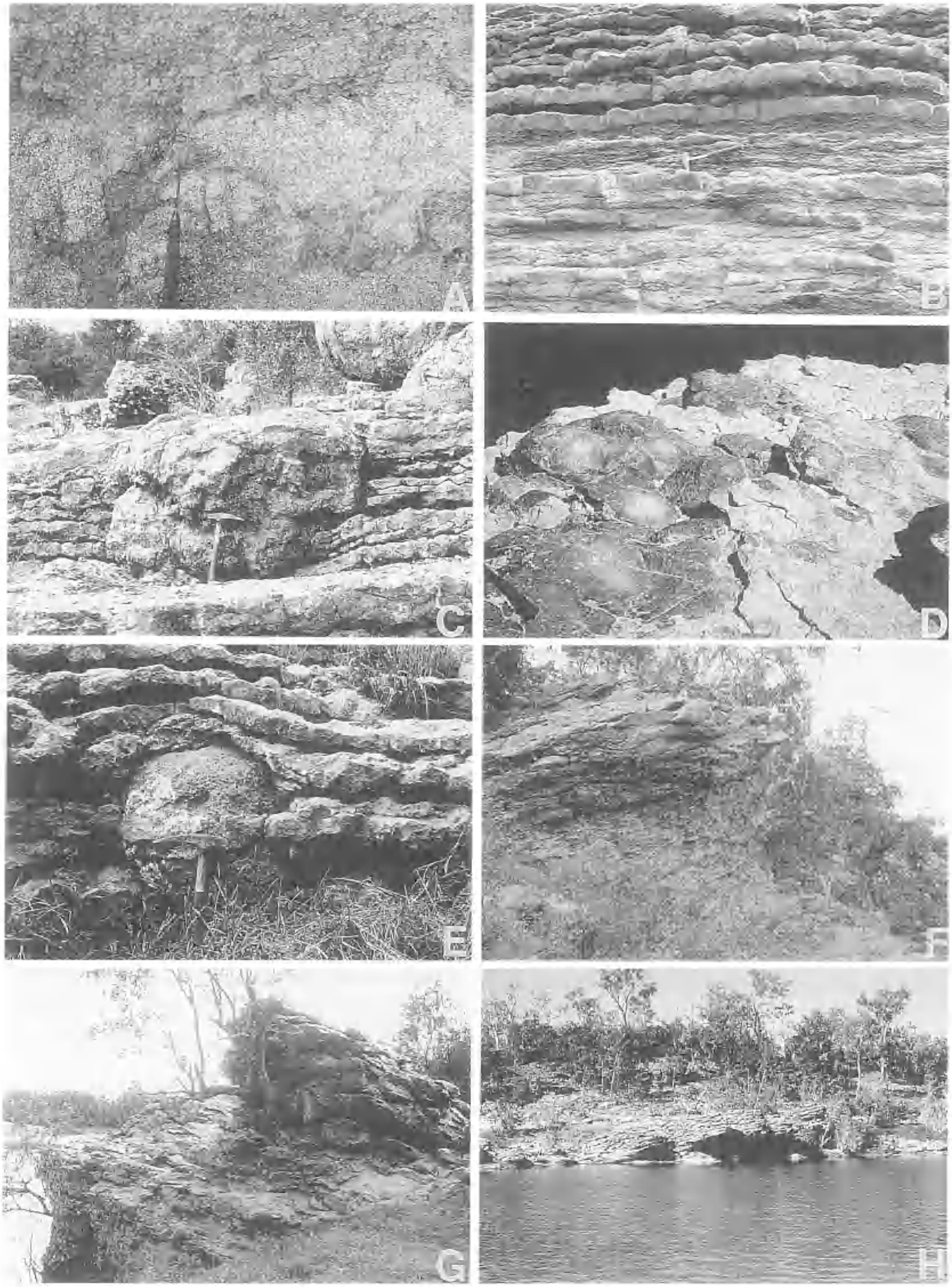
FLETCHERVIEW: L779; 14.5m thick, with basal molluscan packstone coarsening upwards to coquinite, interbedded coarse sandstone, impure wackestone, packstone and carbonate mudstone. BURDEKIN DOWNS: L781; approximately 4m of poorly outcropping coarse sandstone beds with interbedded impure packstone. L784; 8m of impure sandy wackestone and packstone with coarse sandstone interbeds. GOLDEN VALLEY: L800; approximately 30m of poorly outcropping impure wackestone, packstone and coarse siliciclastic sandstone interbeds. HORSESHOE BEND: L787; very poorly outcropping sandy packstone, of indeterminate thickness. FANNING RIVER CAVES: L791; three packages, all poorly exposed, of interbedded coarse siliciclastic sandstone and sandy packstone and wackestone. FANNING RIVER: L 788; and environs; two packages <4m thick of relatively poorly outcropping, fossiliferous coarse siliciclastic sandstone, sandy packstone and wackestone. FANNING RIVER NORTH: L789, L790; approximately 80m of interbedded coarse sandstone, sandy and silty wackestone and packstone.

DESCRIPTION

Coarse terrigenous units interbedded with sandy to silty impure pellet grainstone, wackestone and mudstone are characteristic. Coarse, slightly fossiliferous arkose packages are thick to medium bedded, commonly show low angle cross laminae, sporadically display a lobate plan geometry, and are somewhat discontinuous. Bivalve coquinites (highly impure molluscan grainstones) are present at several localities. Impure, thinly laminated silty and sandy limestone is ubiquitously bioturbated, pelletal and contains an abundant fauna of fragmental and unabraded coral, stromatoporoid and molluscan remains. Pellet grainstones are bioturbated but laminae and cross laminae are commonly preserved. Carbonate mudstones are variably impure, and display vertical burrows as part of extensive bioturbation.

DISCUSSION

The juxtaposition of coarse terrigenous sediments with muddy, albeit impure, carbonates suggests an environment of fluctuating energy. Carbonate lithologies are similar in depositional style to those of the nodular limestone association discussed below. Abundant bioturbation, minor planar lamination and cross lamination, and a delicate fauna coupled with the absence of fenestral limestones supports interpretation as an imp-


A
B
C
D
E
F
G
H

ure muddy carbonate lagoon with water depths of only a few metres (Read, 1973; Hardie & Ginsburg, 1977; Enos, 1983). Toppling and some breakage suggests episodic storm activity.

Sandstones are interpreted to represent mobile sand bars derived from stream outfall which prograded across the adjacent lagoonal floor during periods of high runoff. Interbedding suggests that each unit represents a channel outflow from a small delta or wadi system (cf. Roberts & Murray, 1988) and that the distributary channel or equivalent avulsed (Miall, 1984).

Intercalation of coarse siliciclastic and carbonate lithologies has been reported by a number of authors (Read, 1973; Freidmann, 1988; Roberts, 1987), generally in the context of intertidal to supratidal sediments. Interbedding is considered to result from sporadic, intense events which transport coarse siliciclastics into the marine environment (Roberts & Murray, 1988). Modern nearshore, backreef lagoons are known to contain mobile sand bars, coral pavements and patch reefs (Roberts & Murray, 1988).

Coquina beds, especially those evident at Fletcherview L779, were deposited as a coarsening upwards sequence prior to the deposition of other associational elements. Coarsening upwards trends, the disarticulated state of bivalves and bioturbation especially of lower beds suggests increasing energy of deposition from a relatively quiet lagoonal subtidal floor to high energy, current driven, bivalve-rich, sand bodies. The bivalve debris were likely to have been derived from within the lagoon.

Nodular limestone facies
(Table 4)

DIAGNOSIS

Bioturbated, nodular, impure mudstone and wackestone which contains a scattered, but abundant, dendroid coralline fauna, with patch reefs developed within the upper stratigraphic levels of the facies.

DISTRIBUTION AND THICKNESS

FLETCHERVIEW: L778; 9m of nodular mudstone and wackestone with scattered dendroid fauna and patch bioherms overlying a conglomeratic unit in upper 2m. L779; 7m of section below the biohermal facies, with rare low patch bioherms; some 5m above somewhat impure coral-*Amphipora* rich wackestone-packstone. L780; approximately 2m of nodular lime mudstone and limey mudstone with patch bioherms. BURDEKIN DOWNS: L781; approximately 12m of somewhat impure nodular wackestone containing a biohermal unit in upper part, and minor sand beds in lower part. HORSESHOE BEND: L786; approximately 6m of relatively pure wackestone.

DESCRIPTION

The facies is dominated by thick to medium bedded, nodular mudstone with wackestone patches (Fig. 3B), and diffuse, commonly pelletal, wackestone units containing dendroid stromatoporoids (*Stachyodes*), solitary rugose corals, branching tabulate corals, rare isolated low domical to medium domical chaetetids, stromatoporoids, abundant bivalve hash, and sporadic nautiloid remains. The units are slightly to moderately impure, with siliciclastic impurities consisting of clay, silt and fine sand. Isolated patches of framestone, comprising microatolls or patch reefs up to 1.5m in height (Fig. 3C,D,E), contain low domical to medium domical stromatoporoids, tabulate corals, and have a halo of dendroid stromatoporoids, fasciculate tabulate corals and solitary rugose corals. They take two forms: low diffuse framestone-coverstone patches or bulbous to columnar stacks of framestone. A singular conglomerate unit in the Fletcherview (L778, 780) area is thin and poorly sorted, consisting of granule to pebble sized clasts of coralline debris, granodiorite and minor mudstone intraclasts in a coarse arkosic sandstone matrix.

The nodular fabric characteristic of this facies is a variable feature ranging from isolated lenticular pods up to 60cm in length within a more silty matrix to rather homogenous mottled limestone characterised by irregular bedding surfaces. Although highly variable, the general trend is from isolated nodules in the lowermost parts of the

FIG. 3. A, rounded granitic boulder conglomerate upon unconformity surface at Fletcherview Station L778. Hammer for scale. B, nodular limestone association showing upwards increase in proportion of limestone units. Fletcherview Station L778. C, E, bulbous-like patch reefs within nodular limestone association at Fletcherview Station L778. D, upper surfaces of coverstone style patch reefs within nodular limestone association at L778. F, Lower biostromal association, Burdekin River L781 showing transition from well bedded nodular limestone to laminar stromatoporoid coverstone to framestone. G, framestone outcrop, Burdekin River L781. H, prominent outcrops of framestone L781.

facies prigressing through low sinuosity, coalesced nodules to homogenous mottled limestone in the uppermost parts of the facies. Typically nodular limestone is succeeded by biostromal facies but some sequnces(L781, L779) show the opposite pattern.

DISCUSSION

The facies is interpreted to have been deposited in an inshore sheltered lagoon, mostly removed from destructive wave energy and coarse clastic input, below normal wave base and away from stream outfall. Ubiquitous bioturbation which has resulted in the loss of sedimentary structures, coupled with the abundance of dendroid coralline forms supports this interpretation (Hardie & Ginsburg, 1977; Enos, 1983; Bjerstedt & Feldmann, 1985; Harrington, 1987). The toppling and limited reworking of dendroid forms resulted from episodic increases in current energy, probably related to storms, but this was insufficient to displace larger isolated domical coral and stromatoporoid forms. The presence of some ripple cross lamination in pelletal sediments and limited preferential orientation of *Stachyodes* sp. adjacent to patch reefs also attests to some current activity.

The localised conglomerate unit is interpreted as representing a single storm event which transported siliciclastic debris into the shallow lagoon, mixing it with material from the adjacent shoreline and biostromal environments. This unit allowed many stromatoporoids to gain a purchase upon the substrate and its deposition heralded the development of the small patch-reef buildups in this area.

Two types of small-scale stromatoporoid-coral buildups are represented. Patch reefs (or "bommies") of columnar, bulbous or pillar shape resemble the "rauks" or sea-stacks of Riding (1981) diffuse patches of coverstone-framestone composed of low domical forms fro which skeletal growth matched sedimentation rate. Sediment invagination at the margins of some of the bommie-type patch reefs likewise supports vertical accretion matching the rate of sediment deposition (Kershaw & Riding, 1978). Although the height of these structures is up to 1.5m, the growing surface may have been only a few tens of centimetres above the muddy sea floor.

Decreasing siliciclastic contribution to these units is a function of transgression, with the depositional environment being more distant from the shoreline up-sequence and change in nodular texture is controlled by the complimentary increase in the carbonate components (Moller & Kvingan, 1988).

The average depth of modern, nearshore quiet, carbonate-dominant lagoons varies considerably and is typically 5-30m (Longman, 1981). Analogous inferred environments and facies with dendroid coralline wackestone, mudstone and floatstone from other sequences have been considered as much shallower (Read, 1973; Racki, 1993), as shallow as <1m when associated with intertidal and supratidal facies. Depths of up to 5m for the nodular limestone facies represents a maximum estimate of palaeodepth given proximity to shoreline; and depths of this lagoonal environment to which this facies relates were probably no deeper than this. There is no evidence of emergence.

PROXIMAL SHELF FACIES ASSOCIATION

Stromatoporoid biostromal facies (seven divisions)

(Tables 5; 6)

Stromatoporoid-bearing biostromal units are subdivided into seven distinct facies representing the range of *in situ* stromatoporoid accumulations and their directly related sediments. These are:

Stromatoporoid framestone
Coverstone
Micritic floatstone
Silty rubbly floatstone
Grainy floatstone
Rudstone
Associated packstone and wackestone

Distributions and thicknesses are variable for these often complexly interrelated minor facies and only notable occurrences are listed below.

STROMATOPOROID FRAMESTONE

FLETCHERVIEW: L779, BURDEKIN DOWNS: L781-2.

This facies forms a thick unit of massive to very crudely bedded stromatoporoid framestone (Fig. 3G,H) in which generally low domical and laminar stromatoporoids support a slightly to moderately impure packstone matrix. Smaller framebuilders are chaetetids, heliolitids and foliose alveolitids, mostly in growth position, but many are reoriented. Coarse matrix components are dominantly unabraded and include solitary rugose corals, *Stachyodes*, branching tabulates, molluscs, brachiopods and stromatoporoid fragments. Finer skeletal debris includes crinoid ossicles, mollusc hash and fragmented tabulates. Siliciclastics include fine clays, quartz grains

TABLE 4. Characteristics of inner shelf facies associations; nodular limestone facies. Letter in bold= *in situ*, italicised= fragmental and transported, plain text= reoriented or unabraded. R= rare, U= uncommon, C= common, A= abundant, D=dominant.

INNER SHELF FACIES ASSOCIATION				
Facies	Nodular limestone facies			
Lithology	mudstone	wackestone	patch bioherms	conglomerate
Fauna				
Stromatoporoids				
laminar	U	C	**A**	*C*
low-medium domical	U	C	**D**	*C*
high domical-bulbous	U	**C**	**C**	*U*
dendroid	U	C	C as a halo	*U*
Tabulate corals				
ramose alveolitids	U	A	U	*C*
auloporids	U	C	U	*U*
Heliolites	U	A	U	*C*
domical alveolitids		**C**	U	*C*
foliose alveolitids		C	R	*U*
Rugose corals				
solitary (small)	U	A		*C*
solitary (long/delicate)		C		*C*
Chaetetids	U	C	R	*C*
Bivalves	U	A	*R* in matrix	*U*
Nautiloids	*U*	*C*		
Gastropods		U		
Crinoids		U		
Brachiopods	U	U	R in matrix	*U*
Bedding features				
massive (M), very thick (v), thick(T), medium (m), thin (h)	**T**	**T**	n..a.	**T**
planar lamination				minor
Nodules	**D**	**D**		
Styolites				
sharp high amplitude	U	U	U	
low sinuosity	**D**	**D**		
Grain sizes				
clastics	clay-silt	clay-vfsand		to cobble
carbonates	mud dominant + fauna	mud dominant + fauna		
Bioturbation	extensive	extensive		
Clastic grain types	clay, qtz, bio			qtz, felds, biot, clay, micritic intraclasts, granodiorite
Impurity	<5%	<5%		to 60%
Carbonate fabric	mudstone	wackestone	localised framestone bindstone	

ranging from silt to fine sand, and biotite flakes to medium sand size. Reef-top energy was sufficient to reorient some framebuilders.

DISCUSSION

Stromatoporoid framestone is indicative of *in situ* reefal development (Longman, 1981; James 1983). Lateral facies relationships shows that such reefs were of low relief, standing no more than a few metres above the surrounding seafloor and were locally extensive. The margins of such bioherms were gently sloping rather than steep sided. Broad inter-reef debris channels developed between the bioherms. Reorientation of some larger framebuilders suggest storm or wave turbulence on the reef top (Read, 1973; James, 1983) but the matrix lithology reflects the rather subdued prevailing conditions and many interframe shelters. Recesses were occupied by a number of dendroid and fasciculate taxa including *Stachyodes*, *Sociophyllum* sp. (Zhen, 1991), and alveolitids all rarely preserved in growth position. The preponderance of laminar and low domical stromatoporoid growth forms reflects high energy, hard substrate, encrusting associations in well circulated, well lit, extremely shallow, turbulent water (Lecompte, 1970; Riding, 1981; James, 1983; Kano, 1990). Water depths for the reef were shallow, less than 10m depth (turbulent zone of Lecompte, 1970; Embry & Klovan, 1971), and may have been as shallow as 2-3m (Read, 1973). There is no evidence for emergence.

Siliciclastic components indicate proximity to the shoreline and a terrigenous source. The bioherms were within a few kilometres of shore and can be regarded as fringing reefs (*sensu* Johnson & Carter, 1987; Johnson & Risk, 1987).

COVERSTONE

FLETCHERVIEW: L779, BURDEKIN DOWNS: L781, FANNING RIVER CAVES: L803, HORSESHOE BEND: L787.

Coverstone facies include both laminar stromatoporoid coverstone and foliose alveolitid coverstone. Stromatoporoid coverstone is medium to thickly bedded and consists of large, up to 1.7m wide, laminar stromatoporoids supporting a moderately impure silty wackestone matrix containing dispersed tabulate and rugose corals, molluscs and rare brachiopods. This facies occurs as interbeds with wackestone and packstone (described below) in particular at the base of the major framestone unit at Fletcherview (L779), Burdekin Downs (L781) and also within Fanning River Caves L803 (Figs 3G, 4A). At L787, a thin <2m, restricted unit of foliose alveolitid coverstone with a slightly impure wackestone matrix is interbedded with coralline wackestone and packstone.

DISCUSSION

These units are interpreted as representing sheltered lagoonal deposition in which laminar stromatoporoids grew rapidly laterally in order to gain a purchase upon the muddy substrate (James, 1984). Immediate vertical passage to framestone suggests lagoon floor laminar stromatoporoid pavements that were a pre-reefal, initial stage of reef growth upon a muddy proximal shelf, in water depths less than 5m, or an intra-biostromal lagoonal phase in equally shallow water. Stromatoporoid coverstones thus represent the near-reef development of short lived stromatoporoid communities in a nearshore or proximal shelf environment. Intercalation with packstone and wackestone suggest periodic reworking of bioclastic debris across such communities, but fine grained interstitial lithologies suggest generally quiet lagoonal conditions. Tabulate coral coverstones are relatively pure, medium bedded and locally restricted, and represent very localised tabulate pavement development within the inshore environment of carbonate dominance.

MICRITIC STROMATOPOROID FLOATSTONE

FANNING RIVER: L788. FANNING RIVER NORTH: L789. FANNING RIVER CAVES: L791. KIRKLAND DOWNS: L798. CALCIUM AREA (cf Wyatt et al., 1970: 24).

The facies is characterised by locally extensive, thickly to very thickly bedded floatstone in which dispersed large, low to high domical stromatoporoids which are enclosed in a coral-mollusc-brachiopod wackestone. The facies is interbedded and interdigitated with rubbly floatstone, rudstone and dendroid coral packstone. Faunal elements include stromatoporoids, smaller heliolitid colonies, rare chaetetids and very commonly the large brachiopod *Stringocephalus*. Smaller fossils include dendroid stromatoporoids, particularly *Amphipora ramosa*, branching tabulates and solitary rugose corals, and smaller brachiopods and molluscs. Colonial rugose corals are common in this facies at Kirkland Downs. The matrix is extensively bioturbated, dark and fine grained. Siliciclastic components are generally of low abundance, but lower units in the Fanning River area are moderately impure containing silt and rarer sand sized material. Most skeletal components are simply toppled and show little sign of transport or abra-

TABLE 5. Characteristics of proximal shelf facies association; Biostromal facies continues Table 6. Letter in bold= *in situ*, italicised= fragmental and transported, plain text= reoriented or unabraded. U= uncommon, C= common, A= abundant, D=dominant. 1 Alveolitid coverstone is a variant of this facies.

PROXIMAL SHELF FACIES ASSOCIATION						
Facies	Biostromal facies					
Lithology	Stromatoporoid framestone		Coverstone	Rudstone	Micritic stromatoporoid floatstone	Grainy floatstone
Fauna	frame	matrix				
Stromatoporoids						
laminar	A A	*A*	D *A*		C C C	C C *C*
low-medium domical	D D	*A*	A	C	C A *C*	A A *C*
high domical-bulbous	C C	C		C	C A *C*	A C C
dendroid		U C	C	*C*	R A *C*	A *A* - D
Tabulate corals						
ramose alveolitids		C *C*	C	*C*	C *C*	U *C*
auloporids		U				
Heliolites	C C	C	C	*C*	C *C*	C C *C*
domical alveolitids	C C	C		*C*	C	C C
foliose alveolitids		C *C*	D * 1		C	U? *C*
Rugose corals						
solitary (small)		*CC*	C	C *C*	A	C *C*
colonial					Kirkland Downs area	
solitary (long/delicate)		*CC*			A	U
Chaetetids	C C	C *C*	U	*U*	A	U C *C*
Bivalves		*C*	*U*	*U*	C *A*	*U*
Nautiloids		*U*			*U*	*R*
Gastropods		*U*	*U*	R	*U*	U
Crinoids		*C*	C	C	U	*C*
Brachiopods						
Stringocephalus sp.				C *C*	A A *A*	
atrypids		*CC*	C	R	A A *A*	
other		*CC*	C	U	A A *A*	U U
Bedding features						
massive (M), very thick (V), thick(T)	M		T - h	M, V - T	V - T	M - T
Bedding features	Sporadic lamination in mtx very crude bedding lamination in framestone fabric		crude imbrication			weak cross laminae
Nodules	C				C	U
Styolites						
sharp high amplitude	C			C		C
low sinuosity	A		C		C	C
Grain sizes						
clastics	clay-med sand		silt-vfsand	silt-vfsand	clays	med-coarse sand
carbonates	mud boulder		mud-cobble	to boulder		
Bioturbation	extensive in mtx		extensive		extensive	
Clastic grain types	clay, qtz, biotites		clay, qtz	qtz?, clays	clay	qtz?, clay biotite
Impurity	2-35%			2-20%	<5%	<5%

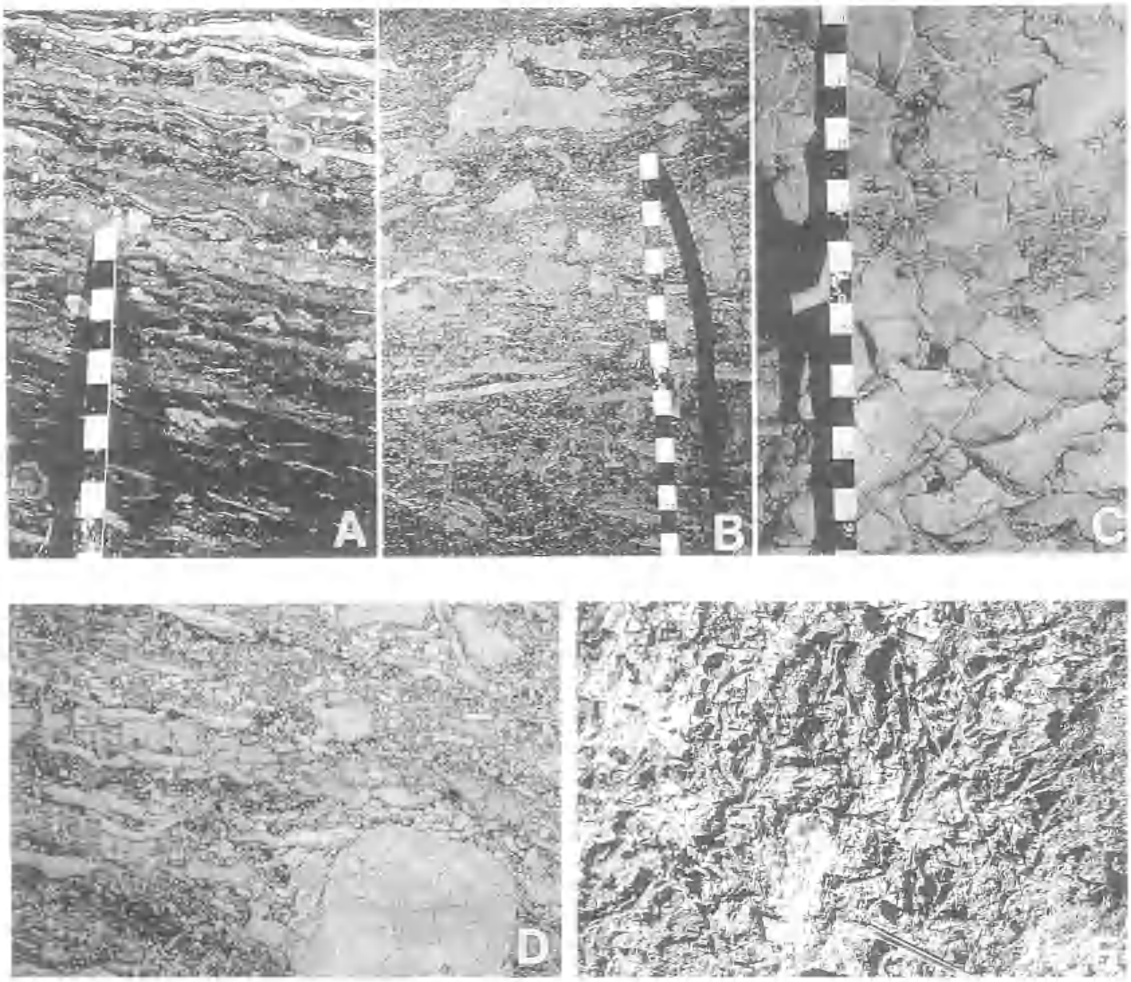


FIG. 4. A, coverstone units interbedded with highly impure packstones and wackestones. B, grainy floatstone. C, massive rudstone unit. D, silty rubbly floatstone facies. All from Maternity Cave, Fanning River Caves L803. E, "Spaghetti stone" fasciculate coral packstone of the coralline packstone facies, Fletcherview L779.

sion. Larger skeletons are *in situ* but some are reoriented. A variant of this facies is represented by beds with an abundance of *Stringocephalus* sp. in the vicinity of Fanning River (L788) and Fanning River North (L789) where large terebratulids and stromatoporoids form a brachiopod-stromatoporoid biostromal unit interbedded and interdigitated with brachiopodal rudstones.

DISCUSSION

The dominance of muddy matrix, delicately dendroid forms and only limited reorientation of larger skeletons suggest quiet water, restricted, shallow conditions. Absence of significant siliciclastics in most occurrences suggests terrigenous input was diminished by distance from shoreline, and/or more proximal biostromes acting as a buffer to siliciclastics thus restricting the terrigenous supply to biostromal zones further offshore. The succession of some biostrome sequences by impure limestone-sandstone association suggests that their development was close enough to shore to be terminated by major clastic pulses.

Extensive *Stringocephalus*-stromatoporoid biostromes are common features in Middle Devonian sequences. Krebs (1974), Burchette (1981), and Racki (1993) regarded them as laterally extensive, sheet-like bodies deposited in lagoonal environments. Substantial accumulations of this brachiopod within a diverse assemblage suggests generally calm lagoonal to peribiostromal deposits (Racki, 1986; 1993). Reorientation of larger skeletons and dendroid toppling suggests some episodic turbulent reworking, whereas intercalation and interdigitation with rubbly floatstone and rudstone indicates local high energy reworking (Racki, 1993; Read, 1973). Water depths were in the order of 1-13m (Read, 1973).

Thus the facies is interpreted as a series of extensive biostromal stromatoporoid pavements interspersed with dendroid coralline-*Amphipora* thickets, in a shallow, quiet water, carbonate-dominant environment.

SILTY RUBBLY FLOATSTONE

FANNING RIVER: L788 and adjacent section. FANNING RIVER NORTH: L789. FANNING RIVER CAVES: L791, L803.

Laterally discontinuous, thick bedded and commonly crudely laminated floatstone contains dispersed stromatoporoid skeletons (Fig. 4D), both *in* and *ex situ*, supported by a moderately to highly impure carbonate matrix containing short tabulate coral sticks, solitary rugose corals and fragmental stromatoporoid, molluscan, and coralline debris. The fine matrix consists of sandy silt and fine skeletal debris such as mollusc hash, crinoid ossicles and coral fragments. A striking feature of the facies is the abundant bioclastic debris. Interbeds with less abraded, coral-rich units, containing branching and more delicate forms are also common.

DISCUSSION

Silty rubbly floatstone represents dispersed stromatoporoid coral biostromes, similar in character to the biostromal pavements discussed above, which were reworked by episodic storm events. Elevated siliciclastic content, and lateral and vertical relationships to siliciclastic facies and basement, suggest a location close to the shoreline. The facies typically overlies either a muddy unit or rudstone. It is intimately associated with micritic floatstone and thus represents moderate energy, stromatoporoid biostromes that were developed at shallow water depths (Leavitt, 1968; Noble, 1970; Read, 1973; Racki, 1993).

GRAINY FLOATSTONE

FLETCHERVIEW: L780, L778.

The facies consists of extremely thick bedded, massive, or very crudely bedded, massive or very crudely laminated stromatoporoid floatstone, possessing large overturned and *in situ* domical stromatoporoids, heliolitids and rare chaetetids set in a supporting matrix of coarse coralline and stromatoporoid debris (Fig. 4B). Coral and stromatoporoid debris range from coarse sand to cobble size and includes fragmented large stromatoporoid bioclasts, common broken sticks of *Amphipora* and tabulate corals and accessory crinoid ossicles.

DISCUSSION

Lateral passage to framestone suggests that this facies represents high energy channels or sheets of debris adjacent to, and between, low relief biohermal buildups. In this sense it can be regarded as representing intra-bioherm reef flats (Longman, 1981). Dendroid *Amphipora* and large stromatoporoids are *in situ* or were derived from subjacent bioherms or *Amphipora* thickets (Tsien, 1981). Fines were winnowed out by wave or current action (Leavitt, 1968; Longman, 1981). These deposits must have been, in part, storm generated in the shallow proximal shelf between and adjacent to bioherms. Water depths were possibly up to 3m (Wilson, 1974), consistent with the low relief inferred for local bioherms. Crude lamination and bedding suggesting depths of 1 to 3m (Read, 1973; Wilson, 1974).

RUDSTONE

FANNING RIVER: L788. FANNING RIVER NORTH: L789. FANNING RIVER CAVES: L791, L803.

Various clast supported stromatoporoid conglomerates are grouped into this facies. Such rudstones thick to very thickly bedded and crudely laminated. They are highly variable, ranging from pebbly stromatoporoid bioclast conglomerates to stromatoporoid boulder conglomerates. Fining upwards to rubbly floatstones is common. Grain size is trimodal with large stromatoporoid bioclasts, smaller coral bioclasts and finer subordinate carbonate bioclasts and, more commonly in lower parts of the sequence, siliciclastic silt and sand. Larger clasts display poorly developed imbricattion.

DISCUSSION

Thickest units, such as those exposed within Fanning River Caves (Fig. 4C) may represent reef flank debris deposits (Wilson, 1974; Playford, 1980; James, 1983), but thick bedded units laterally and vertically associated with micritic floatstones represent local reworking of near *in situ* bioclasts by high energy episodes (Leavitt, 1968).

ASSOCIATED PACKSTONE AND WACKESTONE

FANNING RIVER: L788. FANNING RIVER NORTH: L789. FANNING RIVER CAVES: L791, L803. KIRKLAND DOWNS: L798.

This heterolithic facies groups interbedded packstone and wackestone units found in association with other biostromal facies. Medium to thick bedded, ubiquitously bioturbated, packstone and wackestone contains abundant coralline, stromatoporoid and shelly debris within a pure to moderately impure matrix. Units are locally restricted and laterally grade into related biostromal facies. Their textural characteristics reflect the associated biostromal facies: dark micritic wackestone with a branching coral-stromatoporoid biota are associated with micritic stromatoporoid biostromes whereas moderately impure silty packstones are associated with silty, rubbly floatstones.

DISCUSSION

Deposition took place laterally from biostromal units, representing intra- and inter-biostromal sediments accumulated by current activity, where slight variations in depth, wave energy and circulation periodically prohibited biostromal development. Depositional depths werre similar to that of the micritic stromatoporoid floatstone.

SUMMARY

The biostromal association represents variable development of reefoid deposits: stromatoporoid biostromes, low bioherms, pavements and their associated sediments, within a variety of proximal shelf environments ranging from very nearshore banks to offshore carbonate shelf.

Siliciclastic impurities within facies and siliciclastic pulses between facies packages confirm that many of these reefoid communities were proximal to the shoreline and were thus "fringing" in the modern sense of fringing reefs (James, 1983; Johnson & Risk, 1987; Johnson & Carter, 1987). Two fundamental styles developed:

(1) In the Fletcherview-Burdekin Downs area the main reefoid phase is the coverstone-framestone-grainy floatstone assemblage which represented a low relief bioherm, with leeward flanking stromatoporoid pavement upon a muddy substrate and inter/intra biohermal channelised coarse skeletal floatstone accumulations.

(2) In the Fanning River Area, and subordinately elsewhere (Kirkland Downs, Calcium *see* Wyatt et al. 1970, and other basin margins) extensive biostromal stromatoporoid-coral-brachiopod biostromes developed across much of the proximal shelf, extending very close to the shoreline. Unit outcrop and local variation suggests that individual stromatoporoid biostromes were wide and laterally extensive over several hundreds of metres to kilometres, but were patchy, contained large zones of storm worked rubble, and quieter slightly deeper, large stromatoporoid-poor areas. Some channels or localised erosional slopes of coarser rudstone developed throughout the bank complex.

Dispersed stromatoporoid packstone facies (Table 6)

DIAGNOSIS

Thick-bedded, fasciculate coral packstone with dispersed laminar stromatoporoids.

DISTRIBUTION

HORSESHOE BEND: L787. BIG BEND: L792, FLETCHERVIEW: L806.

DESCRIPTION

Whereas this association could be placed within the biostromal group of facies it is sufficiently distinct to warrant separation. Thick bedded coralline packstone, with abundant fasciculate corals contains very common, but widely dispersed, laminar to low domical stromatoporoid skeletons up to 0.8m wide, scattered heliolitids and foliose or reptant tabulate corals within a muddy matrix.

DISCUSSION

Deposition appears to have been restricted to offshore, shallow, quiet water seaward of major stromatoporoid bank development or adjacent to it. The facies is interpreted as a transition between true stromatoporoid pavements and offshore coralline thickets. Water depths probably were near the lower limit of biostromal deposition, approaching 5-10m (cf. Read, 1973; Playford, 1980), ranging into slightly deeper water above normal storm wave base (5-20m) (Klovan, 1974; Read, 1973; Racki, 1993). Skeletal debris production can be attributed to storm wave reworking, but in general larger skeletal structures are undisturbed.

Endophyllum siltstone facies (Table 6)

DIAGNOSIS

Patch reefs of colonial rugose corals, heliolitids and rare stromatoporoids enclosed within calcareous siltstones, containing a rich coral-brachio-

TABLE 6. Characteristics of proximal shelf facies association; Biostromal facies continued, dispersed stromatoporoid packstone and *Endophyllum* siltstone facies. Letter in bold= *in situ*, italicised= fragmental and transported, plain text= reoriented or unabraded. U= uncommon, C= common, A= abundant.

PROXIMAL SHELF FACIES ASSOCIATION				
Facies	Biostromal facies		Dispersed stromatoporoid packstone	*Endophyllum* siltstone
Lithology	Silty rubbly floatstones	Associated packstone and wackestone		
Fauna				
Stromatoporoids				
laminar	**C** *A*	*C*	**A** *U*	**U**
low-medium domical	**A** *A*	*C*	**C** *U*	**U**
high domical-bulbous	**A** *A*	C		**C**
dendroid	**C** *A*	*C*	**C** - **A** *C*	**U**
Tabulate corals				
ramose alveolitids	C *A*	C C	C C	A
auloporids	**A** *1	U *U*	C	A
Heliolites	A	U *C*	**C**	**C** A
domical alveolitids	**C**	U *C*	**C**	**C** A
foliose alveolitids	**C**	C *C*	**C**	**C**
Rugose corals				
solitary (small)	C *C*	C	C *C*	C
colonial				**A**
solitary (long/delicate)	C *C*	C	C	C
Chaetetids	**C** C *C*	C *C*	**U**	**C**
Bivalves	*C*	*C*	*C*	**C**
Nautiloids	*U*	*C*	*C*	U
Gastropods	*U*	C	C	U
Crinoids	*U*	*C*	C	
Brachiopods				
Stringocephalus sp.	C *C*	C *C*		U
atrypids				A
other	C *C*	C C	C	A
Bedding features				
massive (M), very thick (V), thick (T)	**M**	**V - M**	**V - T**	**T - M**
planar lamination	SOME CRUDE			**C**
Nodules	U	C	U	C
Styolites				
sharp high amplitude	C	C		
low sinuosity	A	A		
Grain sizes				
clastics	silt course sand	silt-coarse sand	clays	silt-vfsand
carbonates	to boulder	to cobble		
Bioturbation	pervasive, extensive	pervasive, extensive	extensive	extensive
Clastic grain types	qtz, clays, felds, rare granitoids, biot	biot, qtz, clays	clays	qtz, clays
Impurity	<35%mostly 10-15%	highly variable	<2%	up to 50%
Carbonate fabric	floatstone-rudstone	packstone-wackestone	packstone-floatstone	siltstone, patchy framestone

1 common as encrustors

pod assemblage, in the uppermost Burdekin Formation.

DISTRIBUTION

FANNING RIVER CAVES: L791. FANNING RIVER: L788

DESCRIPTION

This facies is the uppermost expression of the Burdekin Formation in the Fanning River area representing a transition to the Cultivation Gully Formation. It becomes increasingly silty (siliciclastic-dominated) up-section where it is characterised by medium bedded, moderately to highly impure, silty, wackestone which grades to variably bioturbated fossiliferous siltstone enclosing isolated colonies or aggregations of *Endophyllum columna columna* up to 1.2m wide. Associated with the *Endophyllum* aggregations are *Heliolites* sp., laminar encrusting stromatoporoids, atrypid brachiopods, laminar and dendroid tabulate corals, solitary rugose corals and rare large sponge colonies. This facies extends, as lenticular bodies into the basal Cultivation Gully Formation.

DISCUSSION

The facies represents quiet water, exclusively subtidal deposition under increasing siliciclastic input where isolated coral colonies and small microatolls developed on the muddy offshore substrate. A shallow (ca.? 20m) water depositional environment above wave base is envisaged for this facies, probably at slightly greater depths than other biostromal units. Minor reorientation and abrasion of coralline and other debris attests to some periodic wave energy, against a background of dominant low energy conditions. The development of coralline microatolls, only 1-2m in size, with subordinate stromatoporoids may be a function of regression and higher clastic input, a slightly deeper water biotope (Lecompte, 1970; Playford, 1980), or better ability of coralline forms to eject clastic particles.

DISTAL SHELF ASSOCIATION

Coralline packstone facies
(Table 7)

DIAGNOSIS

A diverse assemblage of fasciculate coral and *Amphipora* packstone and mixed skeletal packstone, ranging from relatively pure to moderately impure, containing dispersed, mostly domical, stromatoporoids, heliolitids and delicate auloporids or tabulate coral debris.

DISTRIBUTION AND THICKNESS

Most sections major occurrences are :
FLETCHERVIEW: L778; 18m. L779; 38m. L780; 30m. BURDEKIN DOWNS: L781-2; 16m. FANNING RIVER: L788; 52m. FANNING RIVER CAVES: L791; two units 80m, 40m. FANNING RIVER NORTH: L789; 30m approximately. GOLDEN VALLEY: L800 15m approximately. HORSESHOE BEND: L787; four main units, 20-30m thick. Kirkland Downs: L796;11m approximately.

DESCRIPTION

This portmanteau association is a diverse assemblage of relatively pure skeletal packstone and subordinate wackestone ranging from fasciculate coral packstone, *Amphipora* packstone to mixed skeletal debris packstone. The association is locally and regionally variable but in general is thick bedded, bioturbated and contains a diverse coral, brachiopod, and subordinate stromatoporoid fauna. Coralline packstone varies from abraded skeletal packstone to fasciculate coral packstone dominated by toppled and non-abraded faunas (Fig. 4E). *Amphipora*-coral packstones, often moderately impure, contain abundant *Amphipora pervesiculata* and thin *Cladopora* sp. Coralline packstones commonly contain dispersed stromatoporoid, heliolitid and delicate auloporid skeletons. The association is transitional to crinoidal grainstone in the Fletcherview area, but in the type section non-abraded coralline packstone containing abundant brachiopods (especially atrypids) is transitionally replaced by *Endophyllum* siltstone.

DISCUSSION

Deposition of this facies took place seaward of biostromal and biohermal development in open shelf, shallow water. Storm and current reworking of material on the shallow shelf produced abraded deposits, but quiet water, sheltered conditions predominated and resulted in widespread development of fasciculate coral thickets, *Amphipora* thickets and a range of faunally diverse communities. *Amphipora* thickets developed in depths as shallow a 1m (Read, 1973) but lateral relationships, preservation of branched forms and the increasing dominance of tabulate corals suggest a depositional depth near the lower limit of biostrome formation, approaching 20m (Lecompte, 1970; Klovan, 1974; Racki, 1993). Tabulate coral-rich packstone probably represents deeper, well circulated depositional envi-

TABLE 7. Characteristics of the distal shelf facies association. Letter in bold= *in situ*, italicised= fragmental and transported, plain text= reoriented or unabraded. R= rare, U= uncommon, C= common, A= abundant, D=dominant. 1. mostly in bioherms

DISTAL SHELF FACIES ASSOCIATION					
Facies	Crinoidal grainstone	Coralline packstone			Micritic carbonate
Lithology		Amphipora packstones	"Spaghetti stone"	tabulate-coral packstone	
Fauna					
Stromatoporoids					
laminar	**R R** *C*	R *U*	R *U*	R *U* *1	
low-medium domical	**R R** *C*	R *U*		R *U* *1	
high domical-bulbous	**R R** *C*	**R** R *U*		C R *U* *1	
dendroid	*U*	A - D *A*		A - D *1	
Tabulate corals					
ramose alveolitids	*C*	A	A	A *C* C	R *R*
auloporids			A	A *C* C	
Heliolites	C *C*	A	A	A *C*	
domicile alveolitids	C *C*		C	C *C* C	
foliose alveolitids	*C*		C	C *C* C	R *R*
Rugose corals					
solitary (small)	*C*	C	A	A	R
colonial					
solitary (long/delicate)	*C*	C	A	A	
Chaetetids	**R R** *U*	U	U	U	
Bivalves	*C*	C	C	C	
Nautiloids		U	U	U	R
Gastropods	*C*				
Crinoids	*A - D*	*C*	C	C	
Brachiopods					
Stringocephalus sp.					
atrypids					R
other	*C*	C *C*	C *C*	CC	
Bedding features					
massive (M), very thick (V), thick (T)	M	V - M	V - T		T - M
planar lamination	SOME CRUDE				C
Nodules	U	C	U		C
Styolites					
sharp high amplitude	C	C			
low sinuosity	A	A			
Grain sizes					
clastics	silt-coarse sand	silt-coarse sand	clays		silt-vfsand
carbonates	to boulder	to cobble			
Bioturbation	pervasive, extensive	pervasive, extensive	extensive		extensive
Clastic grain types	qtz, clays, fspar, rare granitoids, biot	biot, qtz, clays	clays		qtz, clays
Impurity	< 35% mostly 10-15%	highly variable	< 2%		up to 50%

ronments possibly as deep as 25-30m (Klovan,1974; Playford,1980).

Crinoidal grainstone facies
(Table 7)

DIAGNOSIS

Thick-bedded, skeletal grainstone containing abundant, sand-sized coral and crinoidal debris that is commonly planar laminated or rarely cross-laminated.

DISTRIBUTION AND THICKNESS

FLECTHERVIEW: L778; approximately 5m. BURDEKIN DOWNS: L781; approximately 4m.

DESCRIPTION

Thick bedded crinoidal grainstones show prominent but restricted development in the vicinity of Fletcherview-Burdekin Downs where they are transitional from coralline packstone and form the uppermost well exposed units of the Burdekin Formation in that area. Grainstones are thickly to very thickly bedded, sporadically cross bedded, weakly laminated and sporadically cross-laminated, and contain moderately well-sorted, granule sized skeletal debris including crinoid ossicles, commonly with micrite rims, and rare ooids. Larger tabulate corals and stromatoporoids are present, but are mostly *ex situ*. Siliciclastic components are restricted to uncommon, fine, quartz grains.

DISCUSSION

Deposition took place within a well circulated, shallow environment, removed from clastic input where tidal and other currents produced carbonate sand dune bedforms (Ball, 1967; Enos, 1983; Bjerstedt & Feldmann, 1985). Water depths may have been as shallow as 3-5m (Ball, 1967). Given the estimated depths for the underlying coralline packstone, and the sporadic presence of large stromatoporoids, a range of <20m is estimated (cf. Embry & Klovan, 1971; Klovan, 1974). As for the coralline packstone facies, leeward bioherms restricted siliciclastic input to this facies. There is no positive evidence for emergent shoaling.

Micritic carbonate facies
(Table 7)

DIAGNOSIS

Poorly represented, thick-bedded dark carbonate mudstone with rare wackestone patches.

DISTRIBUTION

GOLDEN VALLEY: thickness indeterminate, greater than 100m.

DESCRIPTION

This facies is developed to the SW of Golden Valley, where it is at least 100m thick overlying the coralline packstone facies. Local folding and faulting prevents accurate assessment of the thickness. Monotonous, medium bedded, dark grey, micritic carbonate mudstones enclose rare patches of coralline and brachiopod wackestone. Macrofauna is sparse and includes rare nautiloids, very rare tabulate corals, rare solitary rugose corals and uncommon atrypid brachiopods. Bioturbation is common throughout. Minor silicification is evident but detrital clastic impurities so common in other facies are absent.

DISCUSSION

The fine grained, micritic texture and the paucity of shallow water benthos suggests this facies represents quiet "deeper" water shelf deposition in comparison to other associations of the Burdekin Formation. Deposition occurred beneath wave base and the presence of a sparse benthos suggests that deposition was at the local limits of coralline development in low circulation, low light conditions. Estimates for depth are between 25-80m (see Playford, 1980; Noble, 1970; Embry & Klovan, 1971). Given the small scale of the Burdekin carbonate system, a shallower, rather than deeper deposition within this range is suggested.

RELATIONSHIPS

Facies and facies association relationships are highly complex within the Big Bend Arkose and Burdekin Formation. Although a general successional trend is apparent, local facies mosaics are complex and reflect local nuances in basement topography, biostromal and biohermal architecture, source of siliciclastic input, and other local palaeogeographic conditions. Lateral facies variations indicate spatial relationships between environments across the shallow shelf. A discussion of these trends is presented in terms of individual areas: Fletcherview-Burdekin Downs, Fanning River Caves-Fanning River-Fanning River North, Horseshoe Bend-Golden Valley, and other scattered areas.

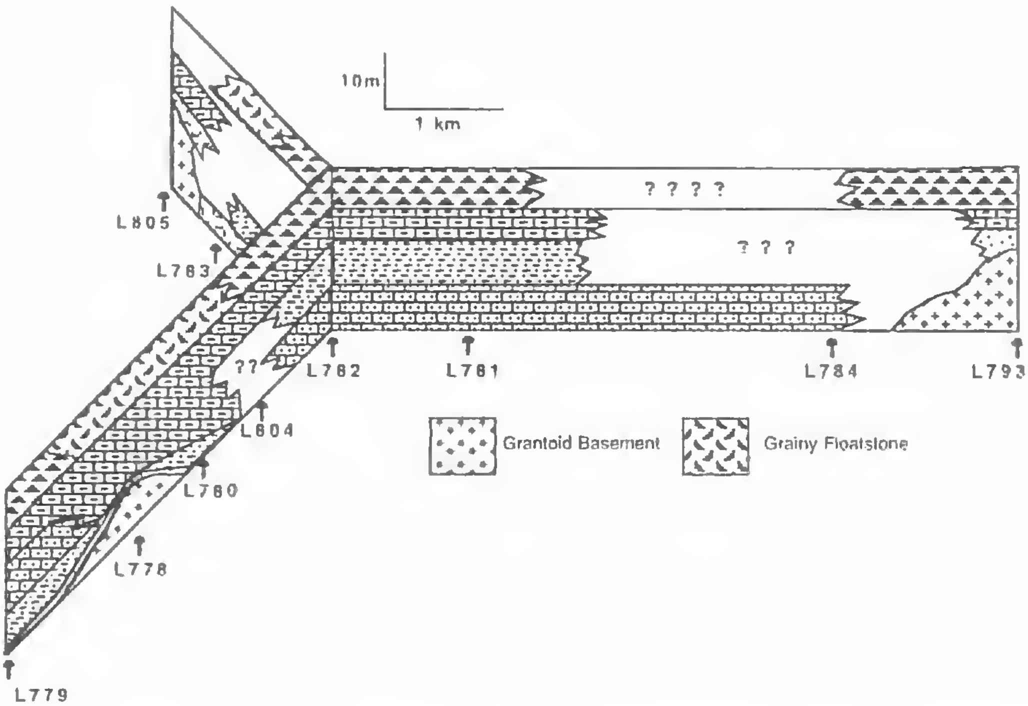


FIG. 5. Interpreted inner and proximal shelf facies mosaic of the Fletcherview-Burdekin Downs area. Legend as for Fig. 2 except as indicated. Scale approximate.

FLETCHERVIEW-BURDEKIN DOWNS AREA

Inner Shelf Association

Almost all basal units are marine with non-marine facies present at only one locality (L783). Boulder conglomerates at L805, L793 and L780 suggest headlands at these sites. Sandy siliciclastics are poorly represented within basal units; the area was dominated by low energy inshore depositional environments. Transition to carbonate-dominated environments was generally rapid; but fluvial outfall near L779 resulted in deposition of impure limestone-sandstone facies. Growth of small stromatoporoid bommies (patch reefs or "rauks") in the proximal carbonate muddy lagoon was widespread, a prelude to the main biohermal phase in this area. Thicknesses of inshore associations are greatest at L781 and L779. All thicknesses suggest that the inshore "lagoonal" deposition was of limited extent in time and space, with reefal development less than a few kilometres offshore. Lateral relationships (Fig. 5) suggest that L778 was locally high, L779 more proximal to river outfall, and lagoonal sediments at L778 generally removed from siliciclastic input.

Proximal Shelf Association

Stromatoporoid framestone at L779, and as seen in the continuous outcrop between L781 and L782, dominates the proximal shelf facies in this area. These framestones transitionally overly patchy coverstones which suggest a back reef gradient from laminar stromatoporoid lagoon to bioherm proper which was laterally extensive along and across the shelf floor. Lateral passage to grainy floatstones at L778 and L780, and patchy stromatoporid framestone at L806, suggests a reefal mosaic (Fig. 5). Biohermal growth in the vicinity of L779 was terminated by a siliciclastic pulse, now represented as impure (biotite-rich) *Amphipora* and coralline packstones. This further indicates the proximity to terrigenous sediment supply of this locality. Detrital influx was a short-lived episode, followed by coralline packstone indicating the development of coralline thickets. Biohermal development subsequently waned in the Burdekin Downs area (L781-2), and replaced by coralline packstone

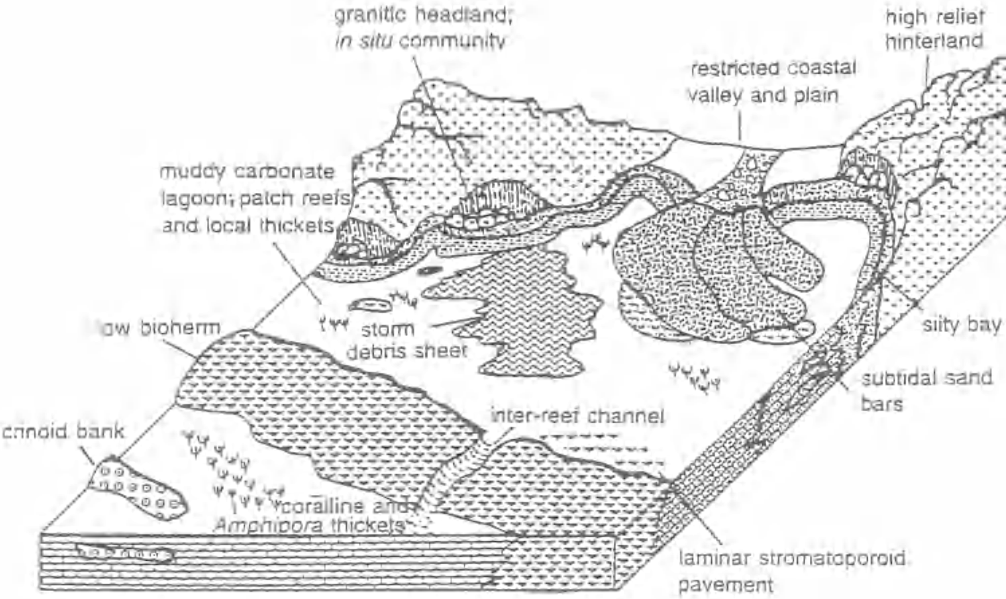


FIG. 6. Reconstructed palaeogeographic and depositional setting for the Fletcherview-Burdekin Downs area.

representing tabulate coral-*Amphipora* thickets. Adjacent higher energy facies were also succeeded by coralline packstone marking the gradual transition to distal shelf facies.

DISTAL SHELF ASSOCIATION

Thick successions of coralline packstone are best interpreted to represent a wide, shallow, stable, distal carbonate shelf, seemingly extensive across the majority of the area. Individual successions of coralline packstones are locally variable, especially in the units immediately above the biostromal facies. At both Burdekin Downs (L781-2) and Fletcherview (L779) the succession is from *Amphipora*-rich thickets to more tabulate coral-rich units. Scattered stromatoporoid colonies and groups of colonies suggest the fore-reef zone was patchily developed. Sporadic occurrences of larger stromatoporoids throughout highlight the shallow nature of the distal shelf. At Burdekin Downs (L781), delicate tabulate coral and heliolitid communities are interspersed with *Amphipora* thickets. Spectacular occurrences of rugose coral-tabulate coral-*Amphipora* rich facies or "spaghetti stone" at Fletcherview (L779) show major development of delicate coral-stromatoporoid thickets in the fore-reef shelf. Crinoidal-rich grainstones in this area show development of some mobile carbonate sand bodies on the distal shelf floor.

A reconstructed palaeogeography for the Fletcherview area is presented in Fig. 6. It depicts a thin inner shelf, wide biostromal zone and extensive carbonate distal shelf. This area lacks thick siliciclastic development, is dominated by facies of quiet water aspect and has true reefal development.

BIG BEND

Outcrops at Big Bend have been studied by a number of authors (Heidecker, 1959; Lang et al., 1990; Zhen, 1991). Re-examination of this site revealed an abundance of marine siliciclastic units, a thin interval of inner shelf facies, and substantial development of the proximal shelf, dispersed stromatoporoid packstone facies. Distal shelf coralline packstone marks the upper part of the succession.

An abundance of inner shelf siliciclastics contrasts sharply with the sequence displayed at Fletcherview, reflecting the localised occurrence of such facies. Thin, mixed facies elements such as fossiliferous siltstone and inner shelf impure nodular limestone suggests that the siliciclastic to carbonate transition was abrupt. Extensive biostromes did not develop in this immediate area. Rather, dispersed stromatoporoid packstone represents the lateral equivalent of reefal facies developed at Fletcherview and Burdekin Downs.

Coralline packstone is the only manifestation of the distal shelf association. Thus this area is interpreted as having been proximal to terrigenous outfall, possessing a broad siliciclastic inner shelf, a thin transitional zone and a low gradient, extensive, dispersed stromatoporoid-coral bank tract grading seaward to coralline thickets.

FANNING RIVER AREA

This area incorporates the Fanning River Caves section (L791), Fanning River type section (L788) and sections to the north (L789/790). Maximum thickness of the Fanning River Group is attained in the vicinity of L791, and throughout this area the lower part of the group is diverse with a complex facies architecture. The interpreted facies mosaic (Fig. 7) forms the basis of a reconstructed palaeogeography presented in Fig. 8.

NON-MARINE ASSOCIATION

Non-marine units were mapped to the immediate north of the base of section L791. They outcrop poorly in restricted to a few shallow gullies, and consist of sandstones interbedded with red-brown shales. A better representation of nonmarine strata occurs in section L789, where interbedded red shales and coarse clastics are prominently exposed within deep erosional gullies. The units are dominated by coarse arkose and are demonstrably discontinuous at both sites, suggesting restriction to topographic lows on the palaeosurface. It is succeeded by fossiliferous sandstone facies, highlighting the continuance of local siliciclastic input during the early deposition of marine units.

INNER SHELF ASSOCIATION

Topographic relief at the base of the Fanning River Group in the immediate Fanning River area (L788) was demonstrated by Wyatt (1973) and Wyatt and Jell (1980) and is confirmed in this work. It is shown to have a bearing on inshore facies architecture, particularly for the sequences displayed by the type section. The scale of relief in this area is illustrated in Fig. 7.

Lowermost abraded bioclast, siliciclastic facies is replaced by fossiliferous siltstone facies which lenses out to the immediate south, suggesting deposition in a relative topographic "low" of the palaeosurface. Such facies represent a silty embayment adjacent to granitic headlands. Increased numbers of branching coral assemblages suggest a wide seafloor tract, just inshore of the biostromes where coralline forms flourished in a silty environment. Minor biostromes in these units shows patch reefoid development in a truly fringing setting.

To the north, fossiliferous sandstone facies is locally succeeded by impure limestone facies units, but units of both types are discontinuous. This suggests a palaeogeography in which some creek or river outfall was present near L789/790. Large volumes of coarse siliciclastics did not extend to L788 where finer grained sediments dominated the lower "pre-biostromal" depositional phase. There is, however a strong, fine siliciclastic signature to these lower units. Siliciclastic dominance at L791 is also suggestive of terrigenous outfall.

PROXIMAL SHELF ASSOCIATION

Lower parts of the sequence in the Fanning River area (L788) suggest that biostromal development took place very close to shore. To the immediate south of the type section biostromal units occur only a few metres above the unconformity, and show characteristically coarse siliciclastic-rich matrices. Within the type section, the lowermost biostromal units have silty matrices and developed adjacent to the embayment described above. All these lower units are locally discontinuous and probably never formed extensive banks. Higher in the sequence units become less terrigenous in content and more laterally extensive. Biostromal units are relatively thin and were, therefore, short-lived, having been terminated by emplacement of storm debris units or siliciclastic depositional pulses. Relationships between facies elements of the biostromal association in this area are complex (Fig. 9). Micritic stromatoporoid floatstone is interbedded with rubbly floatstone, rudstone and *Amphipora*-coral packstone. All units are laterally discontinuous. They represent the development of extensive stromatoporoid-brachiopod biostromes which were commonly reworked by storm events. Storm energy was sufficient to fragment most skeletal material *in situ*, or nearly so. The preponderance of these units attests to the frequency of storm reworkings in an otherwise quiet carbonate shelf setting. Such events probably restricted the development of a major bioherm in this area.

A 19m fining upwards sequence of rudstone passing to coverstone-wackestone within Fanning River Caves (L803, Fig. 10) is indicative of the thicknesses of biostromal "packages" in the Fanning River Caves area and attests to the high-energy reworking of biostromal units.

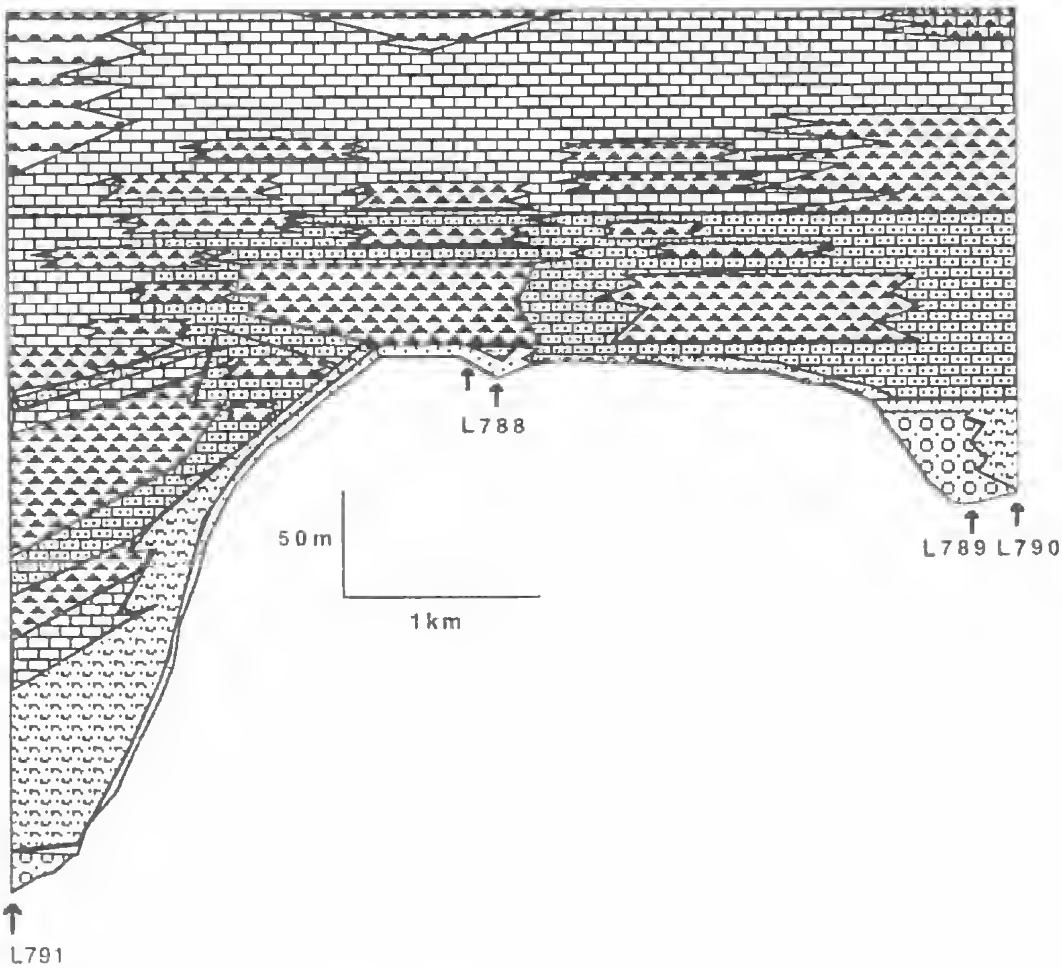


FIG. 7. Interpreted facies mosaic for the Fanning River area. Key as per Fig. 2.

Endophyllum siltstone facies within the uppermost interval of the sequence at Fanning River (L788) and Fanning River Caves (L791) represents the initiation of regression transitional to deposition of the Cultivation Gully Formation. This facies was deposited on the proximal shelf showing increasing siliciclastic input, with the development of isolated patch bioherms of corals and, rarely, stromatoporoids.

Distal Shelf Association

Coralline packstone associations are a testament to the maximum transgressive phase in this part of the subprovince. They are laterally extensive across the area and show the presence of variable coralline thickets on the distal shelf. The development of distal shelf associations was punctuated by perturbations of relative sea-level which resulted in some biostromal formation as interbeds.

Summary

The Fanning River Group in the Fanning River area is distinct from that displayed in the remainder of the subprovince, showing a general, quiet water biostromal accumulation, punctuated by siliciclastic pulses and storm reworking as rubble deposits. Variable thickness of the group in this area reflects differential subsidence consistent with the development of half grabens as sug-

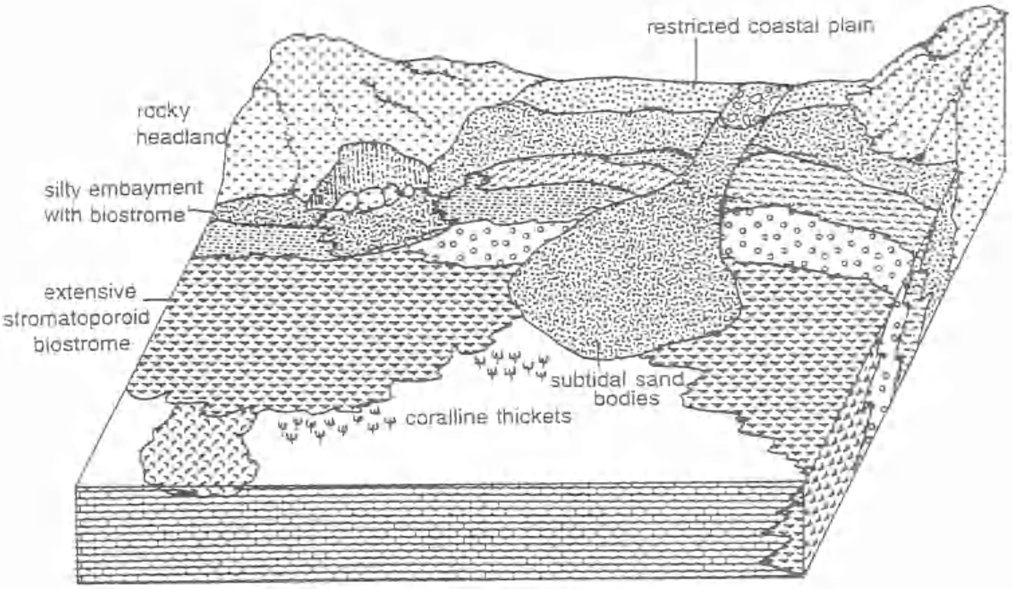


FIG. 8. Reconstructed palaeogeographic and depositional setting for Fanning River area. Key as for Fig. 2.

gested by previous authors (Wyatt & Jell, 1980; Lang et al., 1990). Distal facies are well developed and probably represent the maximum flooding of the subprovince, but there is no biostratigraphic confirmation of this suggestion. These facies are replaced by shallower water units showing an increasing siliciclastic influence during regression culminating in deposition of the Cultivation Gully Formation.

HORSESHOE BEND-GOLDEN VALLEY

Inner Shelf Association

Non-marine facies are well developed in and north of Golden Valley (L800), but are not present at or north-east of Horseshoe Bend. Fossiliferous sandstone facies is thickly and extensively developed within the Golden Valley area, and to the northeast of Horseshoe Bend. At Horseshoe Bend, siliciclastics are restricted to the lowermost few metres of sequence. At L786 this interval consists of granitoid conglomerate and at L787, coral-rich fossiliferous sandstone/conglomerate is present. These occurrences suggest a lowland infill of siliciclastic nonmarine strata in the Golden Valley area. To the west, at Horseshoe Bend, siliciclastic input was not high and was restricted to initial the depositional phase.

Proximal Shelf Association

Poor outcrop within the Golden Valley area has restricted detailed analysis. Here inner shelf impure packstone is overlain by thin biostromal units. These indicate a rapid transition from coarse siliciclastic dominance to a modest inshore mixed facies assemblage followed by a thin interval of biostromal development. Proximal facies developed at Horseshoe Bend are unlike that at Fanning River. They are dominated, particularly in upper units, by impure coral packstone and dispersed stromatoporoid packstone with rare coverstone. Increased siliciclastic input, associated with impure packstone terminated the minor phase of coverstone development.

Distal Shelf Association

Tabulate coralline packstone is relatively thin and is succeeded by a great thickness of micritic limestone. This is thought to represent a higher shelf gradient in the Golden Valley area and the representation of a somewhat deeper water environment in comparison with other parts of the basin.

Summary

The Fanning River Group in the Golden Valley area is atypical. The lower siliciclastic facies are unusually thick, proximal shelf facies are poorly developed and distal shelf facies dominates the

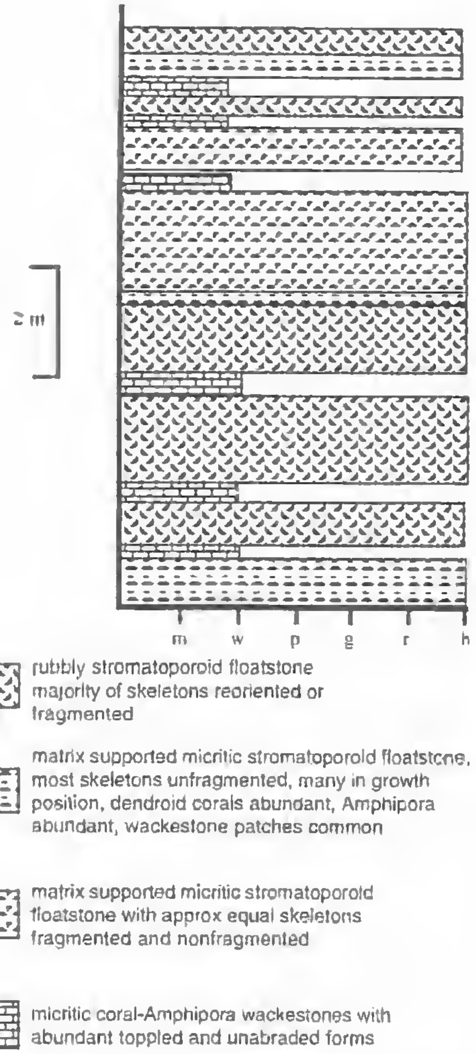


FIG. 9. Log of part of biostromal association relationships for part of section at L778.

upper part of the succession. This pattern suggests that active siliciclastic sedimentation dominated the inner shelf, restricting the development of inner shelf carbonate facies, and that proximal shelf facies deposition was rapidly replaced by a "deeper water" limestone accumulation during transgression.

The Horseshoe Bend sequence shows facies characters typical of both the Fanning River and Fletcherview areas. Basal siliciclastics are subordinate. Biostromal units are poorly developed and are succeeded by a siliciclastic pulse of sedimentation. Carbonate deposition was dominantly in the form of proximal shelf pavements of dispersed stromatoporoids or offshore coralline thickets of packstone facies. There were no true reefal buildups.

KIRKLAND DOWNS

The sequence here rests upon metamorphic basement. Where measured it shows a moderate thickness of nonmarine siliciclastics, thin horizons of inner shelf siliciclastics and a moderately thick biostromal development, succeeded by thin, poorly exposed coralline packstone of distal shelf facies association. Siliciclastic units were localised, reflecting basement topography. The biostromal units developed within this area are atypical of the remainder of the the basin and the biostromal units contain an abundant, diverse colonial rugose coral fauna (Zhen, 1991). In addition, the sequence here is somewhat dolomitised making stromatoporoid identification difficult. The deposition of carbonate units within this area took place at the basin margin in an embayed setting. Conodont assemblages (Talent & Mawson, 1994) suggest restricted, or silled, basinal conditions for the Kirkland Downs area.

PAYNES LAGOON (BOUNDARY CREEK)

The Fanning River Group is restricted to a few metres of coral-quartz-metamorphic cobble conglomerate which overlies an undulating nonconformity surface atop metamorphics. Along strike to the west, impure tabulate coral packstone is present. There appears to be no *in situ* stromatoporoid-coral biostromal development, but, by inference, must have occured nearby to source these rubble deposits. Furthermore localised tabulate coral thickets, formed in nearshore, quiet water embayments. At the western perimeter of outcrop, near Boundary Creek, the Fanning River Group is represented by a shell bed up to 5m thick in which large *in situ Modiomorpha mitchellae* Cook (1993a) form extremely localised bivalve clumps (*sensu* Kidwell, et al., 1986). The facies expressed in the Boundary Creek area probably represent high-stand basin margin deposits.

HERVEYS RANGE

Thin sequences of the Fanning River Group unconformably overlie the Argentine Metamorphics in a series of fault blocks stretching NW

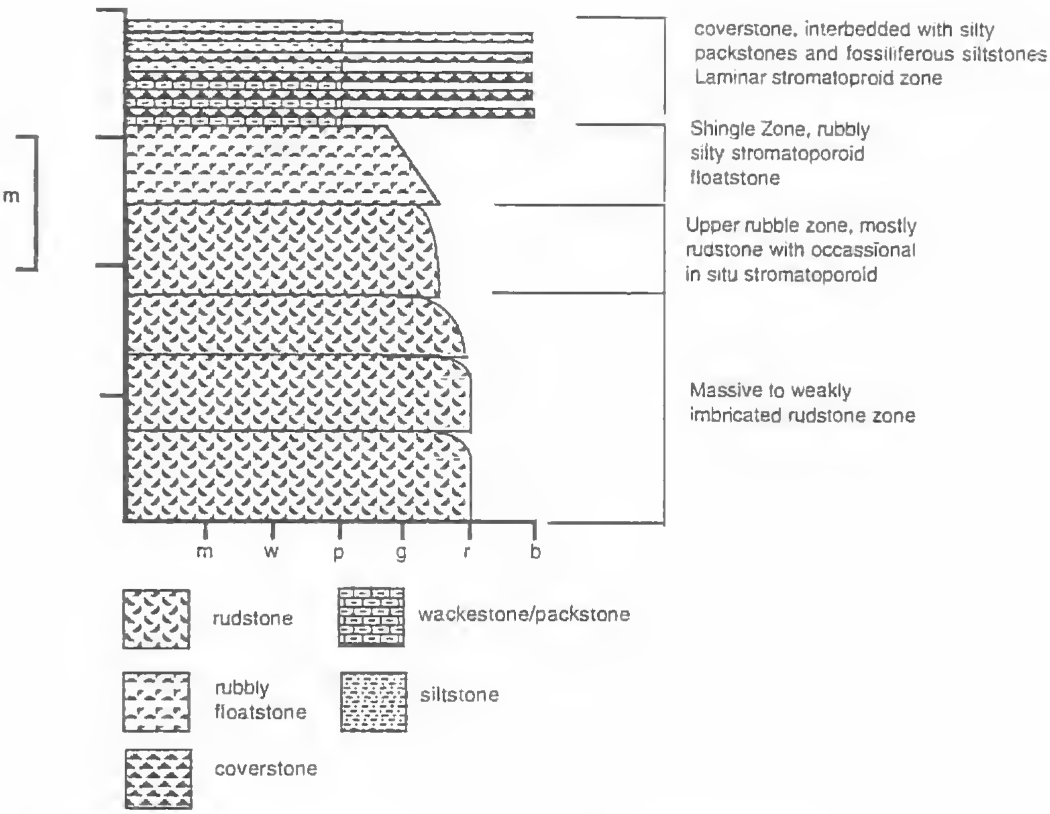


FIG. 10. Log of fining upwards succession exposed within Maternity Cave, JCUL803.

from near Keelbottom Creek (Dotswood 1:100 000 sheet, DU 305 398) to near Fortesque Creek at (Rollingstone 1:100 000 sheet, DU 449 351). Thin basal metamorphic conglomerates of the abraded bioclast, coarse clastic facies are overlain by thin fossiliferous siltstone and biostromal limestone. Other workers (Wyatt, 1973; Zhen, 1991) have provided some detail on these outcrops, highlighting the paucity of biostromal units and the abundance of silty sediments and basal coarse siliciclastics.

CALCIUM-REIDS GAP

A contact metamorphosed sequence of the Fanning River Group crops out in the Reids Gap-Calcium area and was recently quarried by North Australian Cement Limited. Within this area some sequence 350m of coarse marine siliciclastics, probably belonging to the fossiliferous sandstone facies, dominates a somewhat thinner sequence of fossiliferous siltstone, biostromal limestone, and coralline packstone (Lang et al., 1990). Wyatt et al. (1970) noted abundant *Stringocephalus* biostromes in the area.

MINGELA BLUFF

Non-marine Collopy Formation located east of Mingela (Fig. 1) have been variably interpreted as Mesozoic (Wyatt et al., 1970) or Palaeozoic. It occupies the same stratographic position as the Fanning River Group, nonconformable upon Ravenswood Granodiorite. Lycopod and megaspore fossils indicate a Devonian age, no older than Middle Devonian. These units may be terrestrial equivalents of the Big Bend Arkose or may equate to a younger stratigraphic internval Burdekin Subprovince assemblage such as that represented by the Picadilly Formation (as suggested by Draper & Lang, 1994).

MOUNT PODGE

Strata within the Mount Podge area are herein regarded as part of an older depositional phase of the Burdekin subprovince (cf. Talent & Mawson, 1994) and are included only for regional completeness. Basal units in the Mount Podge area are divided into the Laroona Formation and Mount Podge Limestone (Zhen, 1991). Studies of these units by Pacholke (1992) and Zhen (1991) have revealed a thin, highly variable sequence which shows broad sedimentological analogies with the Fanning River Group. Basal clastics overlying Precambrian metamorphics are relatively thick. They consist of metamorphic clast conglomerates succeeded by sparsely fossiliferous pebbly sandstones in turn overlain by sparsely fossiliferous micaceous sandstone. These strata are interpreted as fluvial to shoreface deposits (nonmarine association, abraded bioclast coarse siliciclastic and fossiliferous sandstone facies respectively).

Inner shelf facies in the Mount Podge area are pebbly conglomerate, micaceous sandstone, *Xystriphyllum* floatstone, muddy coral-brachiopod wackestone/ packstone and intraclastic rudstone. Proximal shelf equivalents are represented by stromatoporoid coverstone, rudstone and floatstone. Distal shelf equivalents are crinoidal grainstone and uppermost coralline packstone.

Carbonate facies not represented in the lower Fanning River Group are intraclastic rudstone and quartz granule-coral floatstone. Lowermost carbonate units are highly impure, quartz granule-coral floatstone, representing nearshore *Xystriphyllum* biostromes and muddy impure coral-brachiopod packstone, representing quiet, inner shelf sedimentation. Intraclastic rudstones are developed near the base of the carbonate sequence and indicate early sea-floor lithification of muddy carbonate horizons and/or emergent shoaling in a nearshore environment. Bioherms are not developed in this area, but extensive biostromes of corals and laminar stromatoporoids and rudstones and floatstones attest to significant, high energy reworking of such units. Coral packstone and crinoidal grainstone developed seaward of the biostromes.

CARBONATE PRODUCTION

Primary carbonate sources during accumulation of the Burdekin Formation and Big Bend Arkose were coralline and shelly skeletal debris and the disintegration of codiacean (*Penicillus*-like) algae to form lime mud. Major carbonate producers and sources for each facies association are tabulated (Table 8) and divided into allochthonous and autochthonous catagories.

The primary source for carbonate in the inner shelf were the disintegration of codiacean algae to produce carbonate mud. According to Enos (1983) and James (1984), disintegration of codiacean algae is a primary source of lime mud within the "subtidal carbonate factory" of the modern shelf and was also a major source in the Devonian. Other sources of the inner shelf are molluscs, and dendroid corals.

The proximal shelf was dominated by robust skeletal carbonate production, mainly stromatoporoids, with a significant micrite contribution by algal disintegration.

Distal shelf facies carbonate was provided primarily by coralline and shelly faunas with micritic contribution from algae. Deeper water facies must have gained significant volumes of algally derived-muddy carbonate by transport from adjacent shallower, high-photic zones of the shelf. However, in other facies the carbonate sources were mostly *in situ*, with only transport of carbonate to adjacent facies associations. Quiet water conditions and a biostromal complex in the proximal shelf would have provided some barrier to large-volume transport of carbonate across the shelf.

Bioeroders were present within the Burdekin depositional system and included algae, and probably fungi, as evidenced from widespread micrite rims on skeletal grains. Larger, cylindrical, "trypanitid" type borers, expressed by larger holes in some skeletons are also represented. Endolithic bioerosion has been qualitatively assessed for each facies based on the presence of micrite envelopes and presence of larger borings and micrite films between growth phases in skeletons of larger faunal elements. These are summarised in Table 9. Although some levels of bioerosion are present in all facies, it is clear that endolithic processes were not a dominant source of carbonate within this carbonate system, in comparison to modern reefal settings (Fagerstrom, 1987).

Bioerosion by the micritisation of skeletal grains within coralline packstone facies would have contributed moderate volumes of lime mud to other distal shelf facies. Bored skeletal grains are mechanically weakened (Bathurst, 1975), and more liable to disintegration. However the micrite thus derived cannot account for the volumes present in coralline packstone or micritic carbon-

TABLE 8. Carbonate sources and bioerosion within constituent facies of the Big Bend Arkose and Burdekin Formation.

Facies	Autochthonous producers	Allochthonous components	Allochthonous sources	Rank importance of bioeroision
Abraded Fossiliferous coarse siliciclastic		molluscs, corals	subtidal sand bars, innershelf lagoon	Low
Fossiliferous sandstone	gastropods, bivalves, minor algae. Minor stromatoporoids and corals	corals, stromatoporoids	subtidal carbonate lagoon, proximal biostromes	Low
Fossiliferous siltstone	corals, algae, molluscs, brachiopods, stromatoporoids	minor stromatoporoids, corals	adjacent biostromes	Low- moderate
Nodular limestone	algae, corals, stromatoporoids, chaetetids	minor stromatoporoids, corals	adjacent biostromes	Low
Impure sandstone-limestone	algae, molluscs, corals, dendroid stroms	corals, stromatoporoids	adjacent lagoon and biostrome, some may be reworked from fossiliferous sand bodies	Low-moderate
Biostromal	Stromatoporoids, corals, algae, brachiopods, molluscs	material reworked within biostromal complex	minor reworking from flanking thickets	Low-moderate
Dispersed stromatoporoid packstone	Corals, algae, stromatoporoids, brachiopods, molluscs	material reworked *in situ*	n.a.	Low
Endophyllum siltstone	Corals, ?algae, stromatoporroids, brachiopods	material reworked *in situ*	n.a.	Low
Crinoidal grainstone	corals, stromatoporopids, molluscs	coralline debris, crinoids, molluscan and brachipod debris	coralline packstones, some debris from biostrome	Moderate-Pervasive
Coralline packstone	corals, algae stromatoporoids, brachiopods, molluscs, crinoids	as above derived within thicket complex	some derived from adjacent biostromal complex	Moderate

ate facies. Thus, much of the micrite for these facies must have been derived from codiacean algae.

DEPOSITIONAL SUMMARY

Heterogeneity of depositional style, thicknesses and the absence of basin-wide units reflect significant basement topography at the time of transgression interpreted as reflecting half-grabens (Lang et al., 1990) which were actively forming during deposition. Initial transgression was upon a surface with at least 300m of local relief (Figs 6-8). Restricted coastal plains were developed in local depositional hollows.

The siliciclastic to carbonate transition was rapid, but incomplete, across the inner and proximal shelf resulting in the heterogeneous sedimentary assemblage. Coarse clastic deposition was confined to immediate inshore areas (Figs 6; 8), proximal to stream outfall, but siliciclastic pulses spasmodically strayed onto the proximal shelf. Carbonate lagoons, less than 5m in depth, developed within the inner shelf, leeward of biohermal and biostromal buildups and contained scattered, small patch reefs or bommies. Two styles of large-scale, stromatoporoid-dominated, buildup formed in the proximal shelf: low bioherm (Fig. 6) and extensive biostrome (Fig. 8). Both formed under quiet water conditions punctuated by storm or other high energy events. Water depths were shallow, as little as 1-2m. Buildups occupied zones from innermost shelf adjacent to the shoreline, to a few kilometres offshore and were heavily influenced by siliciclastic sedimentation which commonly resulted in their termination. In places, stromatoporoid buildups and biostromes were

TABLE 9. Rank abundance of micritised grains within lithological samples within the Big Bend Arkose and Burdekin Formation. L = low, M = moderate, A = abundant, P = predominant.

Facies	Samples	Micritised grain abundance
Coarse silciciclastic, marine facies	JCUR32164 JCUR34934 JCUR34935 JCUR34990 JCUR34992	L L M L L
Fossiliferous siltstone facies	JCUR34938 JCUR34945 JCUR34949 JCUR34950	L L L L
Nodular limestone facies	JCUR32113 JCUR32113 JCUR32179 JCUR32180	M-A L-M M L
Impure limestone-sandstone	JCUR32135 JCUR34918 JCUR34921 JCUR34922 JCUR34923	L L L-M M M
Biostromal facies	JCUR34951 JCUR34970 JCUR34967 JCUR34957 JCUF11407 JCUF11409	L-M L-M L-M L L L
Coralline packstone facies	JCUR32116 JCUR32117 JCUR32118 JCUR34895 JCUR34896 JCUR34898 JCUR34978	M M A L-M M M M
Crinoidal grainstone	JCUR32126 JCUR32127 JCUR32128 JCUR32129	A-P A-P A A-P

poorly represented. Instead scattered stromatoporoid pavements formed on the proximal shelf in quiet, shallow water, removed from turbulent disturbance. Seaward of major buildups and banks lay tracts of coralline and *Amphipora* thicket (Figs 6,8), and crinoidal sand bodies distributed across a siliciclastic-poor, shallow, shelf (Fig. 6). Coralline packstone facies represents the maximum transgressive phase for much of the subprovince and was deposited in variable depths, probably down to 25-30m.

Local carbonate mudstone represents deeper water, "basinal" facies with water depths possibly as much as 80m. Coral patch reefs grew in increasingly siliciclastic settings during initial regression to the overlying Cultivation Gully Formation.

Four characteristics of the Fanning River Group are striking: (1) the high siliciclastic component of the "reefal" system. (2) the quiet water style of deposition, punctuated by high energy events. (3) the near absence of emergent carbonate facies. (4) large thickness variation of the group.

Highly siliciclastic biohermal and biostromal facies can be attributed to proximity to the shoreline and terrigenous sediment source. Thus reefal tracts truly represent fringing reefs. Such reefs are well known from the fossil record (e.g. Playford, 1980; Santisteban & Taberner, 1988; Braga Martin & Alcala, 1990) and are well documented in modern environments (e.g. Johnson & Carter, 1987; Johnson & Risk, 1987). Fringing reefs form in a range of different settings: attached to islands or the mainland coast (Johnson & Carter, 1987), adjacent to headlands upon terrigenous sandy and muddy substrates (Johnson & Risk, 1987; Johnson & Carter, 1987), or upon coarse delta lobes (Hayward, 1982; Braga, Martin & Alcala, 1990). For the Burdekin Formation, biostromes developed within quiet clastic bays adjacent to headlands upon muddy substrates, in shallow mixed-carbonate lagoons proximal to coarse siliciclastic shorelines, and in biohermal and biostromal settings, in nearshore mixed carbonate-siliciclastic muddy lagoons.

The abundance of quiet water deposits, punctuated by units representing high energy reworking within the biostromal complex suggests that quiet conditions were the norm with storm conditions sufficiently frequent as to allow thick accumulations of stromatoporoid and coralline biostrome. This highlights the importance of storm or high energy events on the shelf (Kreisa, 1981) particularly on inner and proximal shelf processes (Gagan, Chivas & Herczeg, 1990; Racki, 1993). Storm reworking provided a significant proportion of biostromal units within the Fanning River Group.

The juxtaposition of quiet and high energy deposits interpreted as having been deposited in very shallow water implies that fair weather wave base was very shallow or that most of the inner and proximal shelf was protected. Since no high relief barrier appears to have existed, fairweather wave energy must have been constrained, suggesting a limited fetch for wind generated waves. The Burdekin Basin appears to have been largely isolated from the Palaeo-Pacific ocean to the east, and internally, the Dotswood High (Wyatt & Jell, 1980) would have further constrained wind generation of waves within the basin. Talent & Mawson (1994) have suggested elements of the basin were silled, based on conodont analyses.

The absence of emergent shoaling facies within the carbonate sequence is anomalous in comparison with other shallow water carbonate systems (Read, 1973; Laporte, 1967). Accumulation must have matched the subsidence rate following the initial rapid transgression. Detailed analysis of cyclicity within the sequence would provide a much more detailed depositional history, but has not been attempted here. There were however depositional pulses at the scale of tens of metres, particularly in the Fanning River area, where biostromal units are interstratified with mixed carbonate-clastic facies, or poorly exposed units with elevated siliciclastic impurities. These may reflect minor tectonic movements along basement faults providing clastic pulses into the depositional system during the gentle rifting of the subprovince (Draper & Lang 1994).

The large differences in thickness across the sub province attest not only to relief of the trangressed palaeosurface, but also differential subsidence within the half-graben systems (Lang et al., 1990).

The conodont data of Talent & Mawson (1994) place timing of maximum transgression is as well within the Givetian *varcus* zone for the eastern basin. This is based on presence of late *varcus* zone conodonts from the upper part of the type section. Timing of the initial transgression is problematic. *Stringocephalus* has been recovered in abundance from the basal Burdekin Formation adjacent to the type section (31m above base), but there are no diagnostic conodonts below 119m for the type section. These lowermost index conodonts indicate a middle *varcus* age, but are quickly replaced by late *varcus* age taxa some 5m above. The *varcus* zone may extend well below the 119m level (Talent & Mawson, 1994). Using these data and the presence of *Stringocephalus* sp., the bulk of the Fanning River Group type section must be Givetian, and the 31-119m interval must be within the *hemiansatus* to Early-middle *varcus* zone. Data on the Burdekin Downs section indicate a pre-late *varcus* deposition for the lower half of that sequence. It therefore appears that transgression may have began in the ?latest Eifelian to earliest Givetian, but the majority of carbonate deposition took place within Givetian, prior to the *hermanni-cristatus* zone. Maximum transgression occurred within the late *varcus* zone.

Timing of deposition at basin margins is controlled by presence of *varcus* zone conodonts from Turtle Creek on the Herveys Range (Zhen, 1991) and the presence of ?late *ensensis* to early *varcus* forms within the Kirkland Downs area.

Deposition in the Mount Podge area mostly predates the Burdekin sequence proper. Greater biostratigraphic control for this sequence indicates *serotinus* zone to *costatus* zone ages for most of it, but there is a single occurrence of an at least early *varcus* zone conodont in the upper parts of one Mount Podge section (Talent & Mawson, 1994) indicating a possible Givetian depositional phase. There may be two depositional packages in the Mount Podge sequence with the younger package, probably corresponding to the Fanning River Group further south, mostly removed by erosion prior to deposition of the Myrtlevale Formation, although there is nly questionable stratigraphic evidence for this at Mt Podge.

Unfortunately the absence of high resolution biostratigraphic control on deposition prohibits estimates of the rate of transgression, subsidence, contemporaneous fault movements, individual buildup events, or subsequent regression. Eastern Australian transgressive cycles during the Devonian have been discussed by Talent & Yolkin (1987) and Talent (1989) who commented that the *varcus* zone transgression had not been recognised in Australia. Regression in the middle to upper *varcus* zone within the Mytton Formation, Broken River Province (Talent & Yolkin, 1987; Talent, 1989) appears to predate regression to the Cultivation Gully Formation in the Burdekin Subprovince.

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APPENDIX

LIST OF LOCALITIES.

Localities refer to register numbers for Department of Earth Sciences, James Cook University of North Queensland. Grid references are from the Dotswood 1:100 000 topographic sheet, unless stated.

L778 Fletcherview station, east side of Burdekin River, downstream from "Little Rocks". Section from base of Fanning River Group to approximately 45m up sequence. Dotswood 1:100 000 DU 155027 to DU 157029.

L779 Fletcherview Station, north bank of Burdekin River upstream from "Little Rocks".Section from DU 149025 to DU 144027.

L780 Fletcherview Station, west bank of Burdekin River, downstream from Little Rocks. Section from lower Burdekin Formation, upwards (NE) 40m. DU 153030 to DU 157031.

L781 Burdekin Downs Station, North Bank of Burdekin River downstream from confluence of Arthurs Creek. Section from lower Burdekin Formation at DU 171032 to top of prominent cliffs at DU 169035.

L782 Western equivalent of main framestone unit in L781 at DU 167036, downstream from confluence of Arthurs Creek, Burdekin River, Burdekin Downs Station.

L783 Small un-named tributary of Arthurs Creek, joining at western side of Arthurs Creek near confluence with Burdekin River at DU 165040. Burdekin Downs Station Creek bank section of Big Bend Arkose.

L784 North bank of Burdekin River, Burdekin Downs Station, approximately 2km upstream from homestead. A short section through the Big Bend Arkose-Burdekin Formation transition at DU 180024.

L786 Tributary of Fanning River at Horseshoe Bend west of Horseshoe Bend Mill, Fanning River Station. Short section from unconformity to lower Burdekin Formation at DU 428105.

L787 North Bank of Fanning River at Horseshoe Bend, section along River running east to west from DU 425105 to 418103 along river flat.

L788 Fanning River Type Section, Fanning River, Upstream from Fanning River Station from DU 422204 to DU 417202.

L789 Fanning River North Section, approximately 3km N of Fanning River type section, in gullies from DU 419232 through forest clearing at DU 413230 to DU 410230. Big Bend Arkose to uppermost Burdekin Formation.

L790 Section in gully approximately 3km N of Fanning River Type section, through Big Bend Arkose and lowermost Burdekin Fmn. From DU 417228 to DU 414229.

L791 Section across main limestone hills SE of Fanning River type section, comprising all of the Burdekin Formation at its thickest representation. DU 448194 to DU 433178.

L792 Big Bend, Burdekin River, Burdekin Formation only from DU 093055 to DU 091052.

L793 Outcrop in un-named Creek from base of Fanning River Group at DU 185 026 upstream for approx 100 metres. Burdekin Downs Station.

L794 Isolated rubblecrop containing abundant well preserved stromatoporoids, N of L781 at DU 176037 Burdekin Downs Station.

L796 Kirkland Downs, immediately S of road into property at Hillgrove 1:100 000 sheet 993604.

L798 Paynes Lagoon Station, 200m south of Boundary Creek, approximately 800m to the west of cattle yards at 045 467 Rollingstone sheet.

L800 In Hills 1km NNW of Golden Valley. Section through Big Bend arkose from DU 451115 to 448113. L801 Mount Podge, Laroona Station, Section from northern edge of rhyolite intrusion to top of Mount Podge Limestone along Running Creek. Laroona Formation and Mount Podge Limestone.

L802 Mount Podge Eastern section. Approximately 600m E of Running Creek Section from basal sandstones East of un-named gully N to same Gully, offset 200m E in gully and thence N to base of Keelbottom Group at foot of hill.

L803 Fanning River Caves, Rope Ladder Cave, 18m section of Burdekin Formation, through three main chambers, 3km SE of Fanning River Station; part of L791 section.

L805 Arthurs Creek, small section thorugh basal units at Dotswood DU169048.

L806 Flectherview, immediately N of section L778, small section in cliffs across river from L781/2..